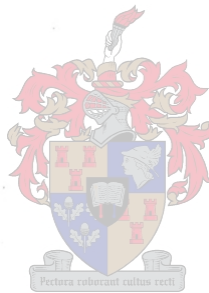


**GIS AND EUREPGAP:  
APPLYING GIS TO INCREASE EFFECTIVE FARM MANAGEMENT IN  
ACCORDANCE WITH GAP REQUIREMENTS.**

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Thesis presented in partial fulfilment of the requirements for the degree of  
Master of Natural Sciences at the University of Stellenbosch.

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December 2003

## **AUTHOR'S DECLARATION**

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

W Schreiber

December 2003

## ABSTRACT

With the inception of precision farming techniques during the last decade, agricultural efficiency has improved, leading to greater productivity and enhanced economic benefits associated with agriculture. The awareness of health risks associated with food borne diseases has also increased. Systems such as Hazard Analysis and Critical Control Points (HACCP) in the USA and Good Agricultural Practices (GAP) in Europe are trying to ensure that no food showing signs of microbial contamination associated with production techniques are allowed onto the export market. Growers participating in exporting are thus being forced to conform to the requirements set by international customers.

The aim of this study was to compile a computerized record keeping system that would aid farmers with the implementation of GAP on farms, by making use of GIS capabilities. A database, consisting of GAP-specific data was developed. ArcView GIS was used to implement the database, while customized analyses procedures through the use of Avenue assisted in GAP-specific farming related decisions. An agricultural area focusing on the export market was needed for this study, and the nut producing Levubu district was identified as ideal.

By making use of ArcView GIS, distinct relationships between different data sets were portrayed in tabular, graphical, geographical and report format. GAP requirements state that growers must base decisions on timely, relevant information. With information available in the above-mentioned formats, decisions regarding actions taken can be justified. By analysing the complex interaction between datasets, the influences that agronomical inputs have on production were portrayed, moving beyond the standard requirements of GAP.

Agricultural activities produce enormous quantities of data, and GIS proved to be an indispensable tool because of the ability to analyse and manipulate data with a spatial component.

The implementation of good agricultural practices lends itself to the use of GIS. With the correct information available at the right time, better decisions can promote

optimal cropping, whilst minimizing the negative effects on the consumer and environment.



## OPSOMMING

Gedurende die afgelope dekade het die gebruik van presisie boerderytegnieke tot verbeterde gewasverbouing gelei, wat verhoogde produktiwiteit en ekonomiese welvarendheid tot gevolg gehad het. 'n Wêreldwye bewustheid ten opsigte van die oordrag van siektekiemegenasies met varsprodukte het ontstaan. Met die implementering van *Hazard Analysis and Critical Control Points (HACCP)* en *Good Agricultural Practices (GAP)*, poog die VSA en Europa om voedsel wat tekens van besmetting toon van die invoermark te weerhou. Buitelandse produsente en uitvoerders word dus hierdeur gedwing om by internasionale voedselstandaarde aan te pas.

Hierdie navorsing het ten doel gehad om 'n gerekenariseerde rekordhouding stelsel daar te stel wat produsente sal bystaan tydens die implementering van GAP, deur gebruik te maak van GIS. 'n Databasis gerig op die implementering van GAP is ontwerp. ArcView GIS is gebruik word om die databasis te implementeer, waarna spesifieke navrae die data ontleed het om sodoende die besluitnemingsproses te vergemaklik. 'n Landbou-area wat aktief in die uitvoermark deelneem was benodig vir dié studie, en die Levubu distrik was ideaal.

Verwantskappe tussen datastelle is bepaal en uitgebeeld in tabel-, grafiek- en verslag vorm. Die suksesvolle implementering van GAP vereis dat alle besluite op relevante inligting gebaseer word, en met inligting beskikbaar in die bogenoemde formaat kan alle besluite geregtig word. Deur die komplekse interaksie tussen insette en produksie te analiseer, was dit moontlik om verwantskappe uit te beeld wat verder strek as wat GAP vereistes stipuleer. Deur die gebruikerskoppelvlak in ArcView te verpersoonlik is die gebruiker nie belaa met onnodige berekeninge nie.

Aktiwiteite soos landbou produseer groot datastelle, en die vermoë van GIS om die ruimtelike verwantskappe te analiseer en uit te beeld, het getoon dat GIS 'n instrumentele rol in die besluitnemingsproses speel. Deur middel van beter besluitneming kan optimale gewasverbouing verseker word, terwyl die negatiewe impak op die verbruiker en omgewing tot 'n minimum beperk word.

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## CONTENTS

<b>FIGURES</b>	ix
<b>1. INTRODUCTION</b>	1
1.1 BACKGROUND	1
1.2 AIMS OF THE STUDY	4
1.3 DESCRIPTION OF THE STUDY AREA	6
<b>2. MATERIALS AND METHODS</b>	10
2.1 INTRODUCTION	10
2.2 STAGE 1: DATA COLLECTION	10
2.2.1 Geographical Data	10
2.2.2 Attribute Data	12
2.2.3 Software and Technical Specifications	13
2.3 STAGE 2: DATA MANIPULATION	14
2.3.1 Geographical Data	14
2.3.2 Attribute Data	15
2.3.2.1 General Information	15
2.3.2.2 Soil Information	17
2.3.2.3 Crop Protection	19
2.3.2.4 Harvesting	21
2.3.2.5 Employees	22
<b>3. SOFTWARE CUSTOMIZATION</b>	24
3.1 GENERAL INFORMATION	24
3.1.1 Display general table	24
3.1.2 Geo-classify general information	26
3.1.3 Calculate area	26
3.1.4 Calculate perimeter	30
3.2 SOIL INFORMATION	30
3.2.1 Show soil analysis table	30
3.2.2 Update soil analysis table	30



3.2.3	Create soil analysis graph	30
3.2.4	Geo-classify soil analysis	32
3.2.5	Show fertilizer application table	32
3.2.6	Update fertilizer application table	32
3.2.7	Create fertilizer application graph	34
3.2.8	Geo-classify fertilizer application	34
3.2.9	Show fertilizer log file	34
3.2.10	Calculate statistics	34
<b>3.3 CROP PROTECTION</b>		<b>35</b>
3.3.1	Show registered products	35
3.3.2	Update product list	35
3.3.3	Show scout information table	35
3.3.4	Update scout information table	35
3.3.5	Create scout graph	37
3.3.6	Geo-classify scout information	37
3.3.7	Show pesticide application table	37
3.3.8	Update pesticide application table	40
3.3.9	Create pesticide application graph	40
3.3.10	Geo-classify pesticide application	40
<b>3.4 HARVEST INFORMATION</b>		<b>40</b>
3.4.1	Show production table	42
3.4.2	Update production table	42
3.4.3	Create production graph	42
3.4.4	Geo-classify production	42
3.4.5	Calculate production statistics	42
<b>3.5 EMPLOYEE INFORMATION</b>		<b>45</b>
3.5.1	Show employee details	45
3.5.2	Update employee details	45

<b>4. EVALUATION OF THE PROJECT</b>	<b>47</b>
<b>4.1 PROJECT EVALUATION ACCORDING TO GAP COMPLIANCE CRITERIA</b>	<b>48</b>
4.1.1 Varieties and Rootstocks	48
4.1.2 Site History and Site Management	49
4.1.3 Soil and Substrate Management	50
4.1.4 Fertilizer Use	50
4.1.5 Crop Protection	52
4.1.6 Harvesting	53
4.1.7 Worker Health, Safety and Welfare	53
<b>4.2 SIGNIFICANCE OF THE STUDY TO THE FARMER</b>	<b>54</b>
<b>5. CONCLUSION AND RECOMMENDATIONS</b>	<b>55</b>
<b>REFERENCES</b>	<b>58</b>
<b>PERSONAL COMMUNICATION</b>	<b>60</b>
<b>APPENDIX A</b>	
<b>APPENDIX B</b>	
<b>APPENDIX C</b>	



## FIGURES

1.1 Research design and report structure	5
1.2 Location of the study area in the Northern Province, RSA	8
2.1 Graphic representation of Chapter 2 and Chapter 3	11
2.2 UML Class diagram	16
2.3 UML Sequence diagram of the fertilizer application process	18
2.4 UML Sequence diagram of the join operation	20
3.1 The general information menu	25
3.2 Orchards classified according to variety	27
3.3 Orchards classified according to number of trees	28
3.4 Graduated symbol map representing number of trees	29
3.5 The soil information menu	31
3.6 pH Values for selected orchards	33
3.7 The crop protection menu	36
3.8 Orchards classified according to number of Stinkbugs (July 2002)	38
3.9 Orchards classified according to number of Stinkbugs (August 2002)	39
3.10 The harvest information menu	41
3.11 Production per orchard (kg) in 2002	43
3.12 Production per tree (kg/tree) in 2002	44
3.13 The employee information menu	46

## CHAPTER 1: INTRODUCTION

### 1.1 BACKGROUND

In recent years, the general trend of increasing agricultural efficiency through the use of larger, more powerful equipment has been superseded by the adoption of information based technologies, such as the use of Global Positioning Systems (GPS), to allow for the precise placement of measured quantities of seed, fertilizer, herbicides and water. Labelled *precision farming*, these techniques allow for the management of variability within field boundaries, i.e. applying agronomic inputs in the right place, at the right time and in the right quantity to improve the economic efficiency, and diminish the environmental impact of crop production.

Along with the greater productivity and economic efficiency that technological development has brought to agricultural activities, the awareness of the health risks from food borne diseases have also increased over the past ten years. On January 25, 1997, President Bill Clinton of the USA announced the National Food Safety Initiative, “a multi agency effort to strengthen and improve food safety in the US”, according to Crutchfield and Roberts (2000). This food safety initiative introduced the implementation of a Hazard Analysis and Critical Control Points (HACCP) procedure to monitor and control food production operations within the United States.

Since the global consumer demands food safety, environmental protection and worker welfare, 118 European retailers founded the Euro Retailer Produce Working Group (EUREP), in February 1997, shortly after the implementation of HACCP in the USA. Being a private and non-profitable organization, the aim of EUREP is to lead fresh produce production to an EN 45011<sup>1</sup>-based accreditation system (comparable to ISO 65<sup>2</sup>), by:

- Encouraging the adoption of commercially viable farming techniques that

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<sup>1</sup> EN 45011: European Norms document 45011, produced by the European Organization for Standardization. Content identical to ISO Guide 65.

<sup>2</sup> ISO 65: International Organization for Standardization Guide 65: General requirements for bodies operating organic product certification systems.



- promote the minimization of agrochemical inputs,
- Developing a Good Agricultural Practice (GAP) framework for benchmarking existing farming techniques,
- Providing guidance for continuous improvement and the development and understanding of best practices.

A standards document (EurepGAP) (EUREP, 2001) for the accreditation of Good Agricultural Practice status to growers and Produce Marketing Organizations (PMO) was devised. The EurepGAP document (Appendix A) allows the implementation of any system that proves to be effective in acquiring the required results, as specified in the document. The EurepGAP Protocol for Fresh Fruits and Vegetables is a detailed document that focuses on ten distinct areas in which growers and PMO will have to prove compliance:

- records on varieties and rootstocks used,
- a recording system for site management, including site history,
- a soil and substrate management plan,
- records of fertilizer usage,
- an irrigation plan,
- records on crop protection measures,
- records on harvesting and post harvest treatment,
- a waste and pollution management plan,
- assurance of worker health, safety and welfare,
- a recording system for impacts on the environment.

Participation in EurepGAP is voluntary and based on objective criteria, but will become mandatory to all growers and PMO wishing to export fresh produce to EUREP member countries as from January 1, 2004. In October 2001, food safety legislation in the USA was amended to ensure that no products showing signs of microbial or pesticide contamination are allowed into the country. Similar legislation in EU countries could prove to be problematic to food exporting countries such as South Africa.

Rupert (1981) indicated that the Republic of South Africa (RSA) is one of only seven net exporters of food in the world, with products such as maize, sugar, deciduous and citrus fruits constituting the country's main food exports. Given the current trend in legislation concerning the production and export of fresh produce, local growers and exporters that rely heavily on foreign destinations for their products have realised the need to conform to European and American standards, such as EurepGAP.

Since the implementation of formalised GAP systems is a very recent endeavour, very little resources aiding GAP implementation are available to the commercial farmer. "Large scale natural resource inventories generate enormous datasets. The ultimate objective is to provide timely, cost-effective and reliable information for making intelligent decisions" (Arvanitis *et al*, 2000). The main objective of GAP and HACCP strategies is to base all actions in the food production process on informed decisions, which is dependent on various sources of data and information. The accumulation of data is meaningless unless it is underlain by a clear definition of how this data will be applied in an informed decision making process. Activities such as agriculture generate large datasets of a spatial nature, and therefore GIS can be an effective tool in the management of this data.

To use of GIS in the implementation of GAP can be viewed as the convergence of two different fields of study. Formalised systems used to measure GAP compliance is a relatively new field of study, hence there is very little published literature on the topic. Maticic (1999) and Smith *et al* (2001) dedicated work to some issues (such as non-point source water pollution and water management) addressed in the GAP document. Agricultural research however, when broken down into sub themes such as water studies, soil studies, Integrated Pest Management (IPM) and precision farming is well covered. Ines *et al* (2001) dedicated a paper to the management of water, since water is a finite resource and because water usage in agriculture is considered highest amongst all water users. A study by Belmonte *et al* (1999), focussing on water saving in irrigated agriculture emphasises this fact. Soil salinisation due to excessive irrigation has been studied by Utset & Borroto (2000), while Lenzi & Di Luzio (1995) applied a GIS to



model non-point source water pollution and erosion associated with agriculture. Earl *et al* (2000) made reference to GIS technology and the importance of applying GIS in the implementation of precision farming. In 1996, Lowenberg-DeBoer wrote: “One of the key factors limiting adoption of precision farming technology is the lack of decision support”.

Although the majority of the above studies focussed on the use of GIS technology in agriculture, no studies have been dedicated exclusively to the employment of GIS in implementing Good Agricultural Practices. The need for a computerized system dedicated to the implementation of GAP requirements on farms was identified as an area requiring immediate attention.

## 1.2 AIMS OF THE STUDY

The objective of this study was to establish a computerized record keeping system, based on GIS technology, to aid farmers with the implementation of strategies that would promote GAP accreditation. Figure 1.1 graphically portrays the research design and report structure. The main aims of the study can be summarized as follows:

- To determine what data needs to be collected and represented in the database,
- how the data should be structured in a logical fashion,
- how the data can be displayed graphically to allow visual interpretation,
- how the data can be represented geographically,
- how to establish real time interaction between different data categories that are interrelated.

The study will focus on generating a database in which GAP specific data can be captured, and then determine how this data can be applied in the decision making process related to farming activities (i.e. fertilization, crop protection and production). Decisions taken regarding fertilization and crop protection measures will be justified by data present in the database. The implementation of all categories, as described in the EurepGAP



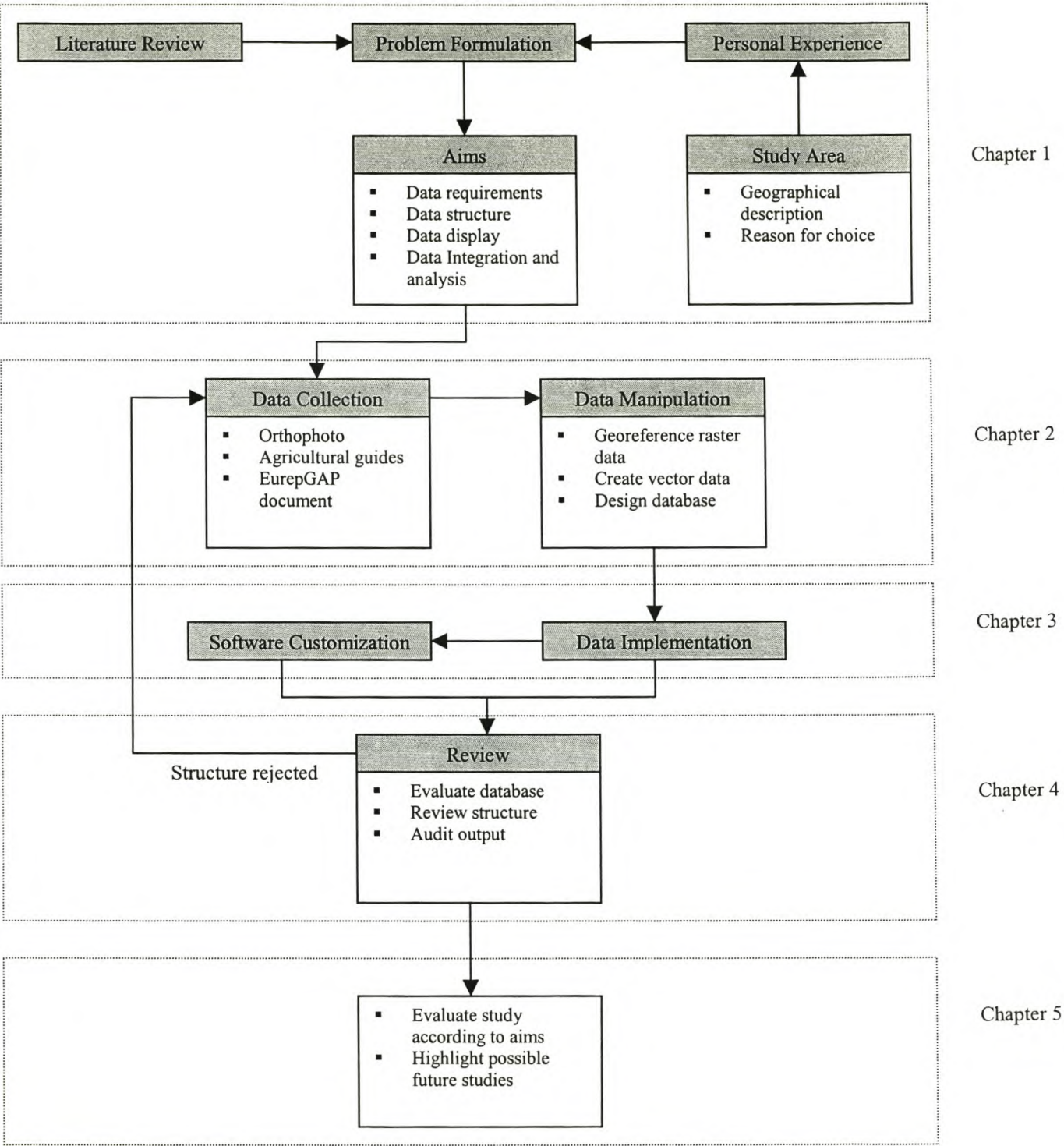


Figure 1.1: Research design and report structure

Protocol: Fresh Fruits and Vegetables, is beyond the scope of this study, and thus the focus will be placed on:

- Category 3: Varieties and Rootstocks
- Category 4: Site History and Site Management
- Category 6: Fertilizer Usage
- Category 8: Crop Protection
- Category 9: Harvesting
- Category 12: Worker Health, Safety and Welfare.

A relational database was developed for the study area, based on the content and structure of the EurepGAP document. Both vector and raster data<sup>3</sup> was collected from various sources and included in the database. Due to the inherent spatial nature of the data needed for GAP implementation, GIS proved to be a suitable tool to be used in the implementation process. The database was implemented in ArcView GIS. Specific queries, used to update and analyse data contained in the database, were designed in Avenue, an object-oriented<sup>4</sup> programming language embedded in the ArcView GIS package. Queries were designed to allow comprehensive data interaction, whilst minimizing user input. This aspect was a fundamental consideration, since prospective users (farmers) operate under severe time constraints. A customized Graphic User Interface (GUI) was created to provide a user-friendly interaction mechanism with the system, whilst performing queries on the data. Data outputs were given in tabular, graphical and geographical format, as well as in the form of onscreen reports.

### 1.3 DESCRIPTION OF THE STUDY AREA

In the process of determining a suitable study area, various aspects had to be taken into consideration. Four major selection criteria to which the proposed study area had to adhere to, were identified:

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<sup>3</sup> See Section 2.2.1 (Chapter 2) for a discussion on data and data sources.

<sup>4</sup> Data are defined in terms of unique objects with relationships between objects.



- Modern farming practices: For a proposed study area to be taken into consideration, it would have to rely on modern farming techniques that would optimise crop yield. This criterion was set since the majority of farmers that deliver to the export market will operate on such a basis.
- Participation in exports: Since GAP and HACCP procedures are based on international standards, a proposed study area should already be a participant in the export community. Should this not be the case, the implementation of GAP or HACCP procedures is not economically justifiable.
- GAP implementation strategy: The implementation of a GAP accreditation procedure should not be a new concept to the owner/manager of a proposed study area. Ideally, the person in charge of a proposed study site must be aware of GAP recommendations and requirements, and the implementation of GAP will be included in the budget.
- Geography: For a proposed study site to be considered, it should be situated in such a way that it is accessible without incurring excessive cost on the side of the researcher.

The farm Nooitgedacht, which is situated approximately 17 km east of Louis Trichardt in the Levubu district (Limpopo Province), between 23° 02' 30" S - 23° 04' 41" S and 30° 01' 22" E - 30° 03' 06" E (Figure 1.2), was identified as ideal, since:

- 36% of the country's total macadamia production is grown in the Levubu district, with 95% of the crop destined for the export market.
- Nooitgedacht operates commercially as part of a company, Bergheim Estate PTY. (Ltd.), and employs the most modern farming techniques. For example, investigations into the use of Integrated Pest Management (IPM) techniques have started.
- Nooitgedacht has been delivering crops to exporting companies such as Royal Macadamia PTY. (Ltd.) and Green Farms PTY. (Ltd.).
- The farm manager has already started an investigation into the accreditation of GAP status on the farm, and GAP implementation strategies have been provided for in the 2002/3 financial budget.

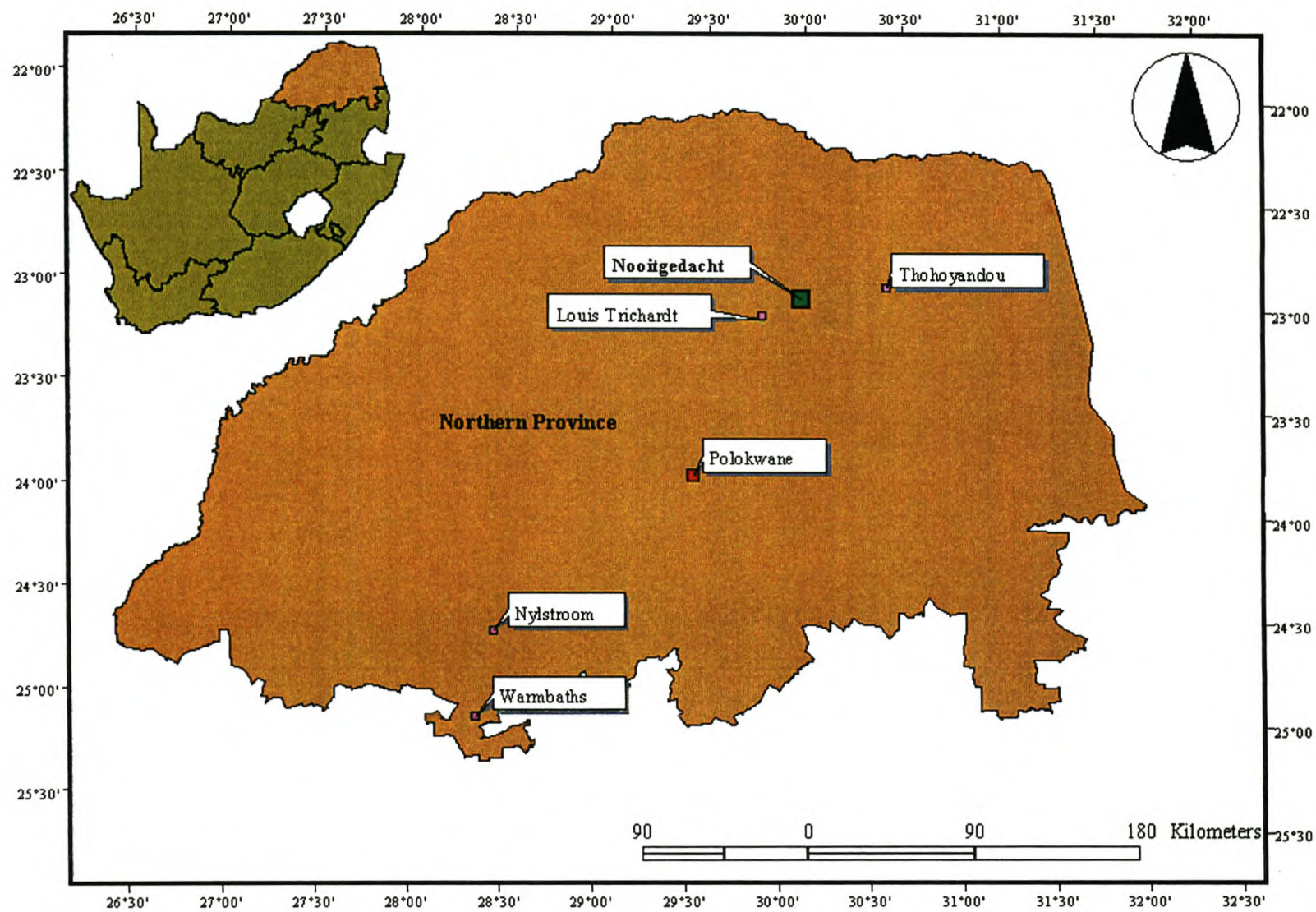


Figure 1.2 Location of the study area in the Northern Province, RSA.



Nooitgedacht occupies a total area of 576 ha. Secondary to the production of macadamia nuts is the production of olives. There are 15 orchards (14 macadamia and one olive) on the farm, occupying 67 ha (11.6% of the total area) with 10 990 macadamia trees and 450 olive trees. In the 2001 growing season, Nooitgedacht had a total macadamia crop of 180 256 kg (wet-in-shell weight<sup>5</sup>), that amounted to a Gross Income of approximately R 1.4 million.

In the next chapter, the materials used and methods followed during the course of the study will be discussed.

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<sup>5</sup> Wet-in-shell weight: Weight of the nut after de-husking but prior to drying.



## **CHAPTER 2**

### **MATERIALS AND METHODS**

#### **2.1 INTRODUCTION**

Since both geographical and tabular (attribute) data is used in a Geographic Information System, this chapter may be divided into two main categories focusing on each of the two data types. Both these sections may then be subdivided into the various themes that contribute to the category as a whole.

The process of data analysis may also be broken down into three distinct and sequential stages, i.e. Data Collection, Data Manipulation and Data Implementation. It is, however, impossible to discuss data and the data analysis processes separately, since they are interlinked logically, as well as in the GIS (Figure 2.1 provides a graphical representation of the layout of chapters two and three). Using the methods followed as the primary base on which this chapter is built, and then integrating the data used during each stage of the process, a holistic view of the study can be obtained.

#### **2.2 STAGE 1: DATA COLLECTION**

During the data collection stage of the research, all spatial and attribute data were collected from various sources. This includes digital vector and raster data, as well as various normative documents such as the EurepGAP document and a number of agricultural guides. In addition to this, the software and hardware requirements were determined.

##### **2.2.1 Geographical Data**

Two different formats of geographical data were used during this study. Raster data refers to spatial data that is expressed as a matrix of cells, with spatial order indicated in the ordering of the cells. One bit, single-band black and white orthophotos of the study area (2330 AB 6) were obtained from the Chief Directorate: Surveys and Mapping at a

## Chapter 2

## Chapter 3

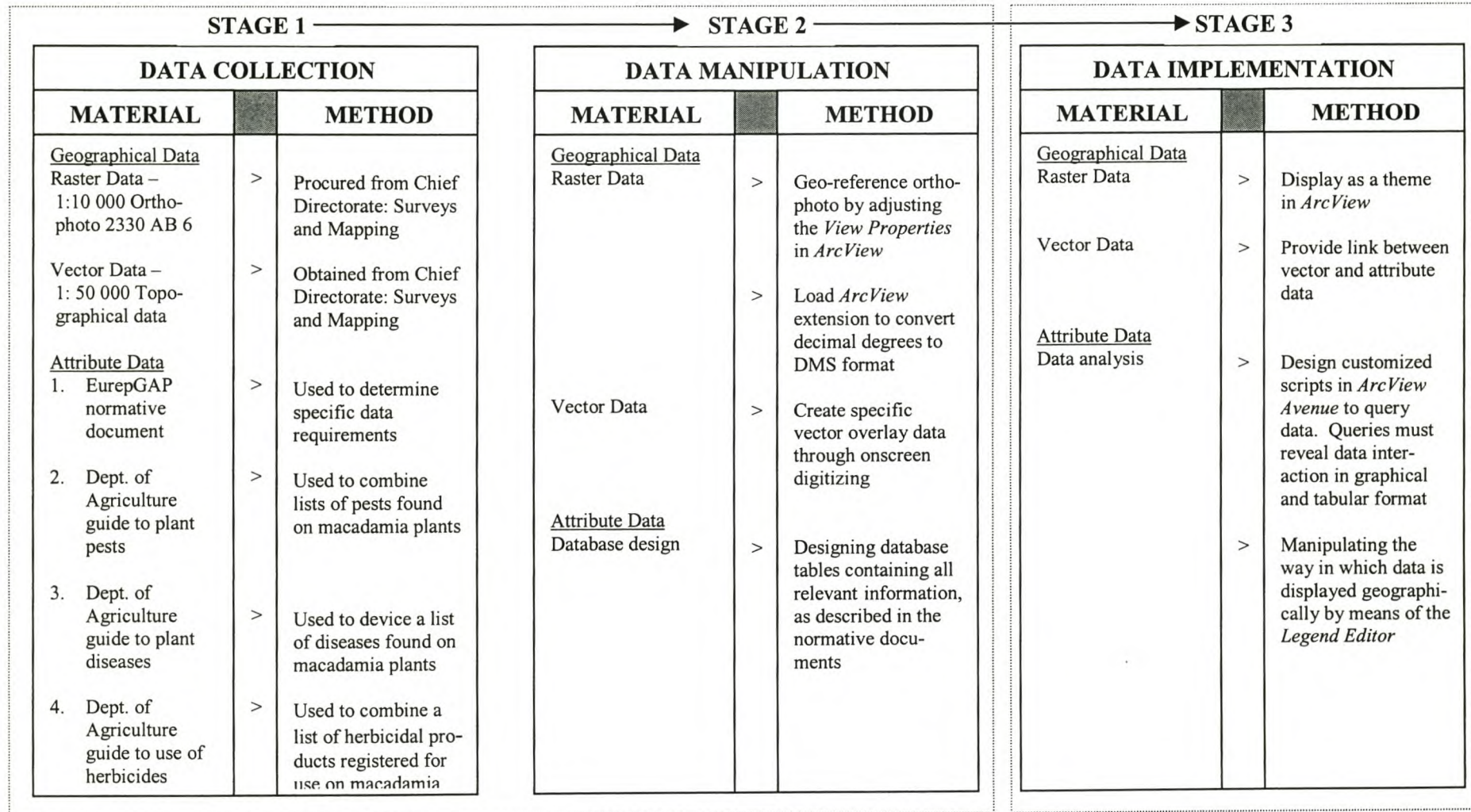


Figure 2.1: Graphic representation of Chapter 2 and Chapter 3



scale of 1:10 000. The data was acquired digitally, as Tag Interchange File Format (TIFF) files. TIFF images contain georeferencing information in the header tags, as defined by the GeoTIFF standard, rendering this format useful for application in GIS software packages.

In addition to the orthophoto images used, selected features of the 1:50 000 digital topographic series, in vector format, was obtained from the Chief Directorate: Surveys and Mapping. Vector data refers to positional information that is stored in the form of points, lines and polygons, and expressed as  $x$ ,  $y$  co-ordinates. The vector data that was incorporated into this study included the following:

- Contours: By including contour data, Digital Elevation Models (DEM) could be created and functions such as analytical hill shading could be performed.
- Single non-perennial rivers: There are two major dams on the farm being fed by two different river systems. By including single non-perennial rivers, these rivers could be indicated without cluttering the scene with all tributaries.
- Dams: Dam area features were included to indicate the size and location of water sources.
- Roads: The R524 between Louis Trichardt and Thohoyandou forms the southern boundary of the farm, and therefore road features were included.

### 2.2.2 Attribute Data

Attribute data refers to the non-graphic information that is associated with geographic elements in a GIS. An extensive array of different normative documents was consulted in order to compile the relevant information needed to build a database that would focus on agricultural activities.

The EurepGAP General Regulations – Fresh Fruits and Vegetables sets out a framework for Good Agricultural Practices on farms, and defines the essential elements for the development of best practice for the global production of horticultural products. Although the EurepGAP document defines the minimum standards acceptable to the

leading retail groups in Europe, it does not provide descriptive guidance on different methods of agricultural production. The EurepGAP General Regulations document (March 2001) was acquired directly from the Eurep web site (<http://www.eurep.org>), free of charge.

Three documents published by the South African National Department of Agriculture (1999) were obtained from the Directorate Communication:

- A guide for the control of plant pests
- A guide for the control of plant diseases
- A guide to the use of herbicides

These documents contain relevant information on all products (pesticides, herbicides and fungicides) that are registered for use on approximately 90 crop types in South Africa. Additional information contained in these documents includes reference to banned and restricted substances, withholding periods after application and a list of registered adjuvants (products used to enhance the efficacy of another product). Additionally, the documents include guidance on the application of chemical products.

### 2.2.3 Software and Technical Specifications

Although a number of GIS packages are commercially available, ESRI's<sup>1</sup> ArcView GIS 3.2 was used for the purpose of this study. ArcView supports various vector, raster and attribute data file formats. ArcView allows the creation of new data, and data created in ArcView is widely supported by and easily incorporated into other software packages. An advantage of ArcView GIS is the fact that data, such as the 1:50 000 topographic vector data, is readily available in the correct format.

Apart from the fact that various data formats are supported by the ArcView package, an integrated *Object Oriented* programming language, Avenue, allows the customisation of the Graphical User Interface as well as the automation of specific tasks. ArcView GIS

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<sup>1</sup> ESRI: Environmental Systems Research Institute



proved to be the ideal software package, since existing vector and raster data were used, new vector data had to be created and certain tasks had to be automated.

The minimum system requirements to run ArcView GIS is a Pentium-based microprocessor with 32 MB physical memory (17 MB virtual memory), running on at least a Microsoft Windows NT 4.0 or Windows 95 operating system. For this study, a Pentium 4 – based workstation with 1.00 GB physical memory, operating on Microsoft Windows XP Professional was used.

## **2.3 STAGE 2: DATA MANIPULATION**

### **2.3.1 Geographical Data**

The first step taken during Stage 2 of the research was to ensure that the orthophoto images were displayed with the correct geographical reference. In order to achieve this, the View Properties of the software had to be altered. The map units used for reference was set to meters, and a custom projection was defined, based on the following information:

- The base projection used was Transverse Mercator
- The spheroid used was WGS 84
- The Central Meridian used was 31°E
- The scale factor was set to one.

With the reference information provided in the orthophoto file header and the adjusted View Properties, the data displayed correctly, but coordinates given was in northings and eastings and not in the standard degree, minute, second (DMS) format. An extension to ArcView (DMS.avx) was downloaded from the ESRI website (<http://www.esri.com>), which allowed for the conversion from northings and eastings to DMS format. Having the data in DMS format would allow the use of data gathered by Global Positioning Systems.



The corrected raster data was used as a backdrop on which the vector data would be displayed. Onscreen digitising was used to create vector overlays, in ArcView shapefile format, representing the 15 different orchards. This file format allows attribute data to be linked to geographic features.

### 2.3.2 Attribute Data

The EurepGAP General Regulations document (EUREP, 2001) (Appendix A) was used to ensure that the most appropriate attribute information was included in the database. Different attribute tables representing different datasets were designed. Figure 2.2 shows a Unified Modelling Language (UML) class diagram, representing the various tables (classes) that were created for the study. A detailed representation of the classes is found in Appendix B. The different attribute data tables can be divided into five groups, focusing on general information, soil information, crop protection, harvesting and employees.

#### 2.3.2.1 General Information

GAP requirements state that growers need to provide up to date records to demonstrate that all activities comply with GAP regulations. The General table was designed to combine information on varieties and rootstocks with information on site history and site management, as indicated in the General Regulations document. This table stores static information such as an ID number and name for each orchard, as well as site-specific information such as the variety of crop planted and the plant date. Physical information such as area (in hectares) and perimeter (in meters) were also included. Four Boolean (TRUE/FALSE) fields were included to indicate whether rootstocks were treated for pest resistance, and also the seed treatment status for the rootstock. The pest treatment status of the soil, as well as the presence or absence of a nursery certificate for the crop was also included. The prior use of each orchard was included, along with the number of trees and plant density. Since the nature of the study area does not require crop rotation, this item was not included in the database.

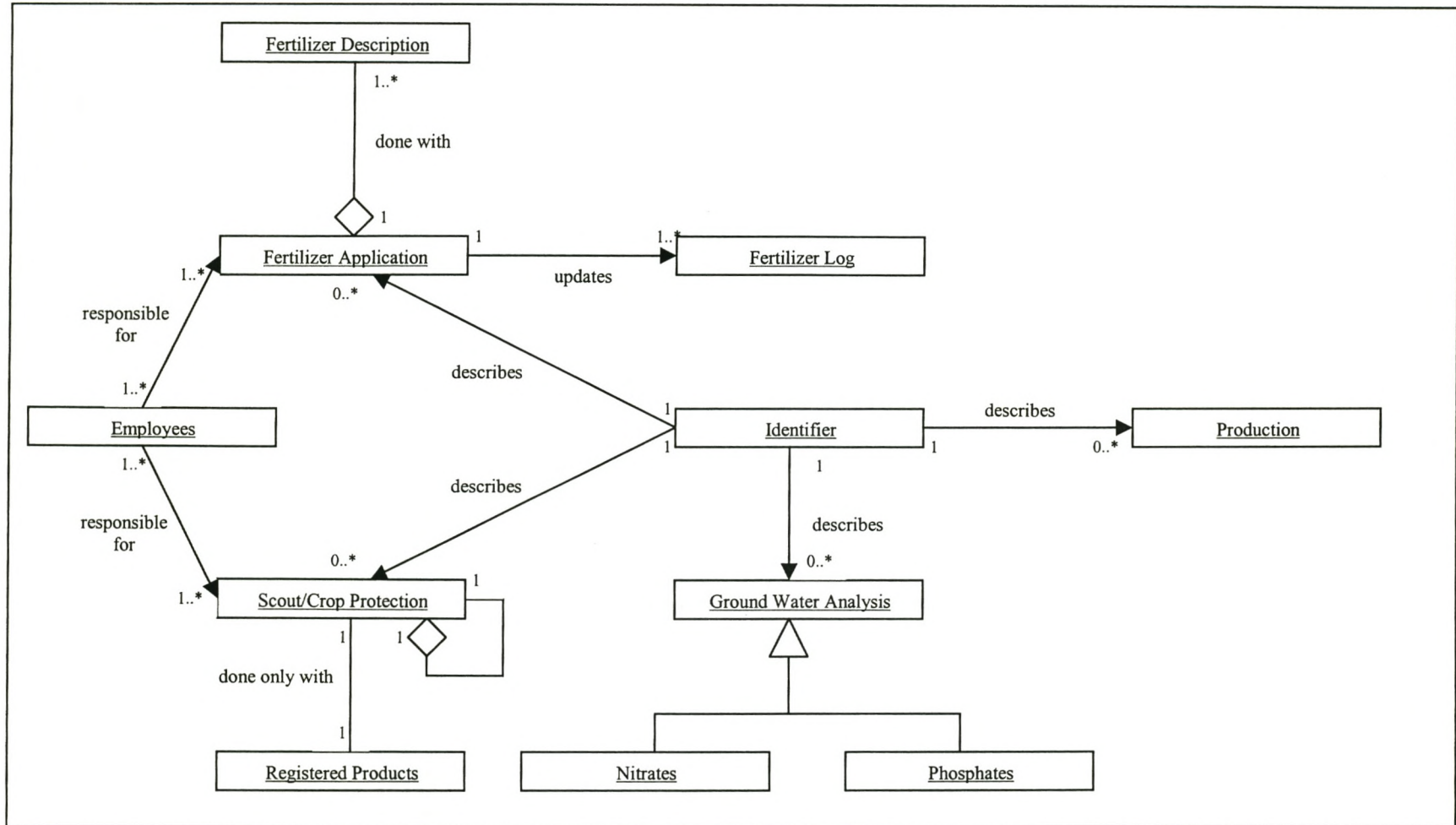


Figure 2.2 UML Class diagram



### 2.3.2.2 Soil Information

Data on soil information and fertilization was divided into five different attribute tables:

- i. Soil Analysis: A soil care plan is encouraged for GAP accreditation, and the application of fertilizers should be based on a calculation of the nutrient requirements of the crop. The soil analysis tables combined all information on soil and substrate management. A unique ID identifies each orchard and provision was made for the laboratory responsible for soil analysis to be referenced. Specific nutrient information in this table included pH and the respective concentrations of phosphorus, potassium, calcium, magnesium and sodium. A new table is created for each year's data. By adding the year to the table name as a suffix, tables were identified as unique. Provision was also made for the benchmark values of each of the above indicators, to allow annual comparison with recommended values. The soil and crop type determines these benchmark values, and recommendations are made annually by the laboratory responsible for the soil analysis.
- ii. Fertilizer Application: According to GAP requirements, the application of chemical fertilizers should be based on knowledge concerning the present concentration of elements in the soil. The format of the fertilizer application table was based on the format of the soil analysis table and designed to work in conjunction with the fertilizer description table. Entries are made for the application of nitrogen, phosphorus, potassium, calcium, magnesium and sodium, for each of the 15 orchards with a unique ID field used to identify each orchard. A new table was created for each year and columns were duplicated for each of the elements, with the date (month) of application as postfix to act as unique identifiers. The fertilizer application table contains the actual amount of each applied element per hectare (e.g. kg N/ha), and not the weight of fertilizer applied. A UML sequence diagram (Figure 2.3) is used to graphically portray the fertilizer application process.



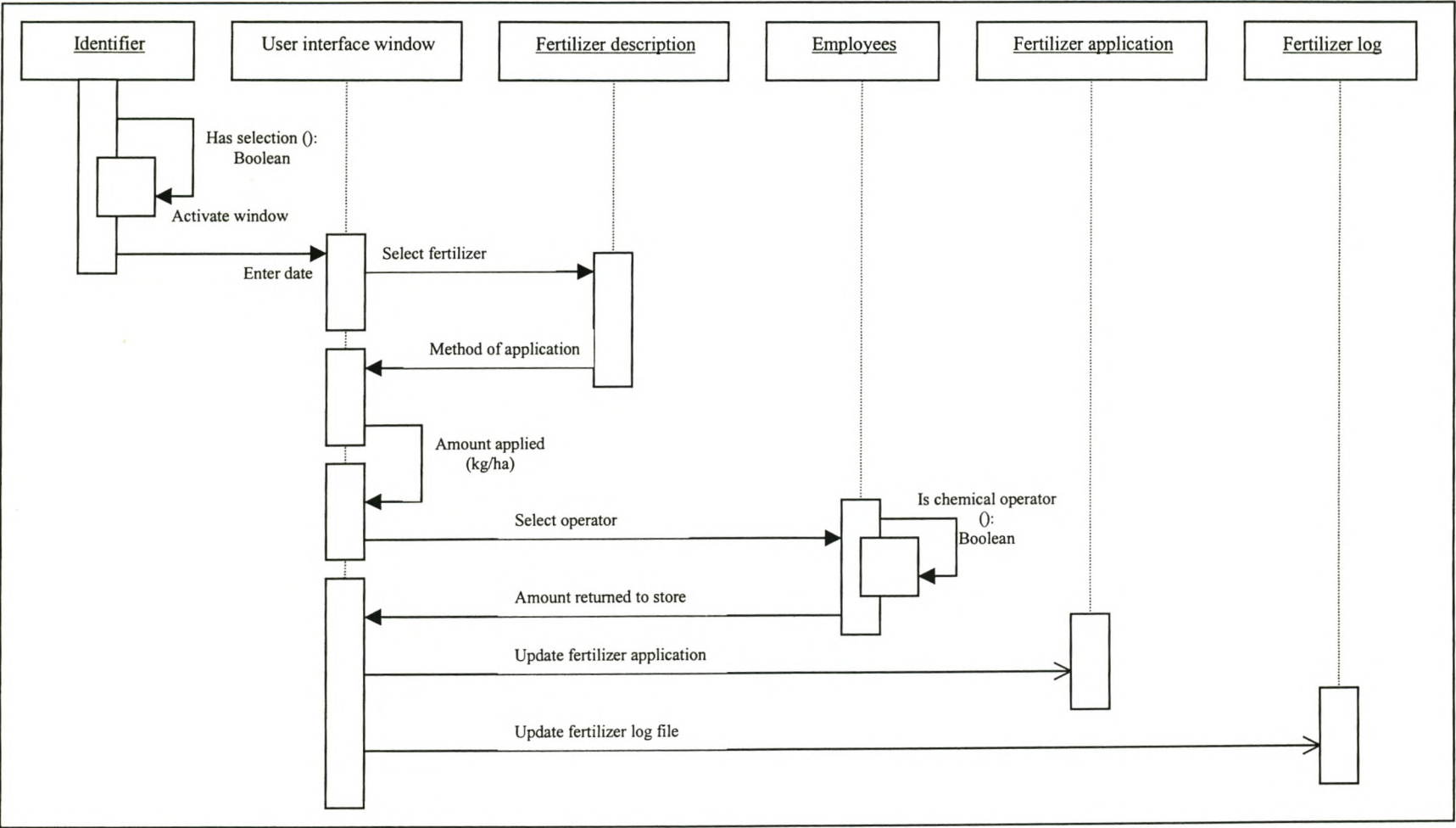


Figure 2.3 UML Sequence diagram of the fertilizer application process

The ArcView join operation was used to append either the soil analysis table or the fertilizer application table to a feature table<sup>2</sup>, based on the common ID field, to prevent duplication of the shape theme. The UML sequence diagram in Figure 2.4 shows the join operation.

- iii. Fertilizer Description: A table containing all chemical products used for fertilization was designed. This table includes the trade name of the product, together with a unique ID. The concentration of nitrogen, phosphorus, potassium, calcium, magnesium and sodium, expressed as a percentage of the dry mass of the product, was included in the table. From this table, the applied weight of each element could be determined for all the listed products.
- iv. Fertilizer Log: A fertilizer log file was designed for each of the different orchards to record all applications of chemical fertilizers. GAP requirements state that the amount of fertilizer applied should balance with the amount taken from the store, and qualified employees should do that application. Provision was made for the date of application, the name of the product used, the method used for application, the amount of fertilizer applied (dry mass<sup>3</sup>), as well as the operator responsible for application.
- v. Fertilizer Storage: The fertilizer storage table contains information on the date, product used, amount taken, amount returned, the balance and the responsible operator.

### 2.3.2.3 Crop Protection

Crop protection is a major aspect of the GAP requirements. Three tables representing crop protection were created and used in conjunction with a feature table.

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<sup>2</sup> Feature tables in ArcView stores attribute and shape information on a set of features.

<sup>3</sup> Dry mass refers to the mass of the fertilizer before diluting/dissolving.

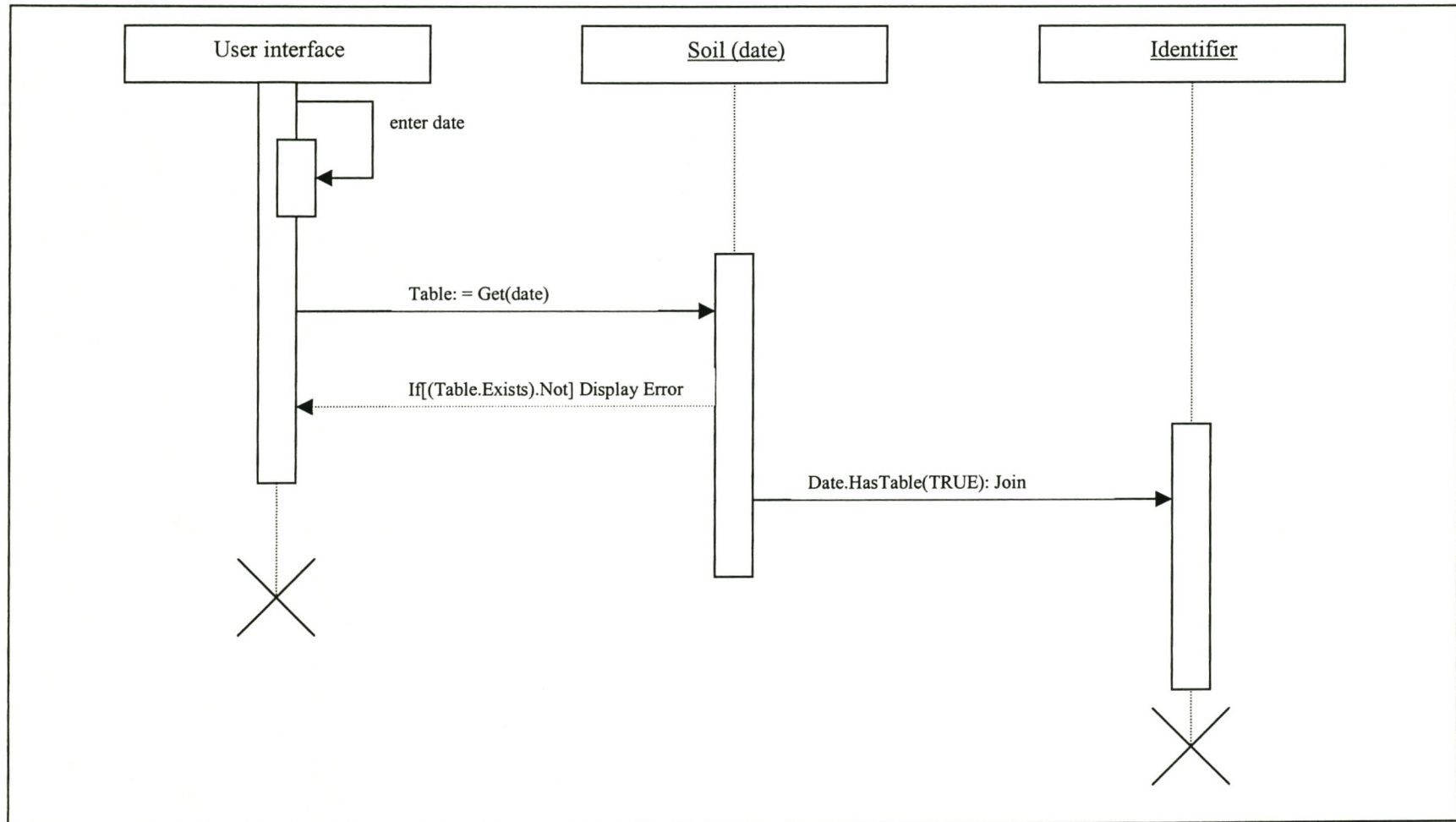


Figure 2.4 UML Sequence diagram of the join operation



- i. Chemical list: The chemical list contains the names of the active ingredients of all pesticides registered for use on macadamias in South Africa that are not banned in the European Union. The list also contains information on the type<sup>4</sup> of product, the formulation, amount active ingredient per weight or volume and the registered dosage. Provision was also made for pre-harvest interval<sup>5</sup> and the pest or disease for which the product is used. The structure of the chemical list was based on the structure used in the guide to the control of plant pests, a document published by the National Department of Agriculture. A no-data value of -9999 was used in each instance where data for a specific entry was not defined. Since the list of available pesticides changes regularly, this list is editable to allow changes to be made.
- ii. Pest Tables: Three tables were created in which data on the occurrence of pests, as well as the application of pesticides were recorded, each focusing on a different pest. Each of these tables was given an ID field and a scout threshold value field. A specific scout value field, a product field and a quantity field, each identified by unique date, were created. The scout threshold field contains the minimum pest level before treatment is justified. The specific scout value shows the number of pest occurrences for a specific date, while the product and quantity fields hold information on action taken for the specific scout value.
- iii. Pesticide Application Table: The pesticide application table was linked to a polygon theme, and given an ID and orchard name field. Pest analysis was done by joining a pest table to the pesticide application table based on the common ID field.

#### 2.3.2.4 Harvesting

Crop yield was included in the project to be used as the primary classifier of activities undertaken on the farm. A different database table was designed for each month of the

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<sup>4</sup> Type refers to suspension concentrate, emulsifiable concentrate, capsule suspension, wettable powder and emulsion, oil in water

<sup>5</sup> The minimum time between last application and harvest.

year, and tables were identified as unique by adding the year and month as a suffix to the name of the table.

Each production table includes a unique ID that allows the table to be joined to a table containing information on the different orchards. Daily entries for each orchard were made possible, and data could be analysed by using the ArcView join command to append the production table to a descriptive feature table.

#### 2.3.2.5 Employees

Good agricultural practice requires that all workers handling and using agrochemicals must receive formal training, and that records regarding employee details be kept. The format of the employee table was based on the information required by EurepGAP, as set out in the section on worker health, safety and welfare in the EurepGAP general regulations document (Appendix A).

A unique ID was used to identify each individual employee, with corresponding entries for surname, first names, date of birth and age. Entries for union membership and pension fund were provided for. Four Boolean fields, representing competence as first aid provider, qualified applicator of agrochemicals, store key holder and driver were included. Reference to general designation and current status was also provided for. South African law as well as EurepGAP require that employees who are in contact with pesticides undergo annual medical examinations. A Boolean field can be included in this table to verify if medical examinations are done annually.

During stage 1 of the research, specific GAP related data were collected from various sources. In stage 2, these data were manipulated in a number of ways:

- The raster data source was referenced and displayed in the correct degree, minute, second format
- Vector data overlays were created for general (farm specific) information, soil analysis information, fertilizer application, pesticide application and production information



- Attribute tables for each of the vector overlays were designed and populated with relevant data
- Additional tables, containing reference data such as fertilizer and agrochemical descriptions were designed. These tables were created to work in conjunction with the various attribute tables.

In stage 3 of the research, discussed in the following chapter, a link between the geographical and attribute components will be established. The ArcView GUI will be customized by adding a number of menus, which will allow users to interact with and analyse the data. Output from user queries will then be produced in tabular, graphical and geographical format.



## CHAPTER 3

### SOFTWARE CUSTOMIZATION

In stage three of the research, a new ArcView project was created. The orthophoto was displayed as a raster theme, and was used as background upon which all other (vector) data sources were displayed. By making use of feature attribute tables, all vector overlays could be linked to their various attributes. A feature attribute table stores geographic information in a '*Shape*' field, in addition to the normal relational data. ArcView supports point, polyline, polygon and multipoint shape types. All the vector data overlays created for this study was of the type point and polygon<sup>1</sup>.

By adding five menus to the ArcView GUI, addressing general information, soil information, crop protection, harvest information and employees respectively, the project was customized. Each of these menus contains customized functions allowing topic specific data analysis. By compiling Avenue scripts<sup>2</sup>, these functions were created.

#### 3.1 GENERAL INFORMATION

The general information menu (Figure 3.1) provides access to data on varieties and rootstocks planted in each orchard, as well as information on site history and management. Four functions were made available in the general information menu.

##### 3.1.1 Display general table

This function allows the user to view the general information table as a table document in ArcView. A table document allows the user to add, update and delete data from the table.

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<sup>1</sup> Polygons represent area features, and are made up of arcs that define the polygon boundaries.

<sup>2</sup> Script: A component of an ArcView project containing Avenue code aimed to automate tasks. Equivalent to a macro language such as AML (Arc Macro Language)



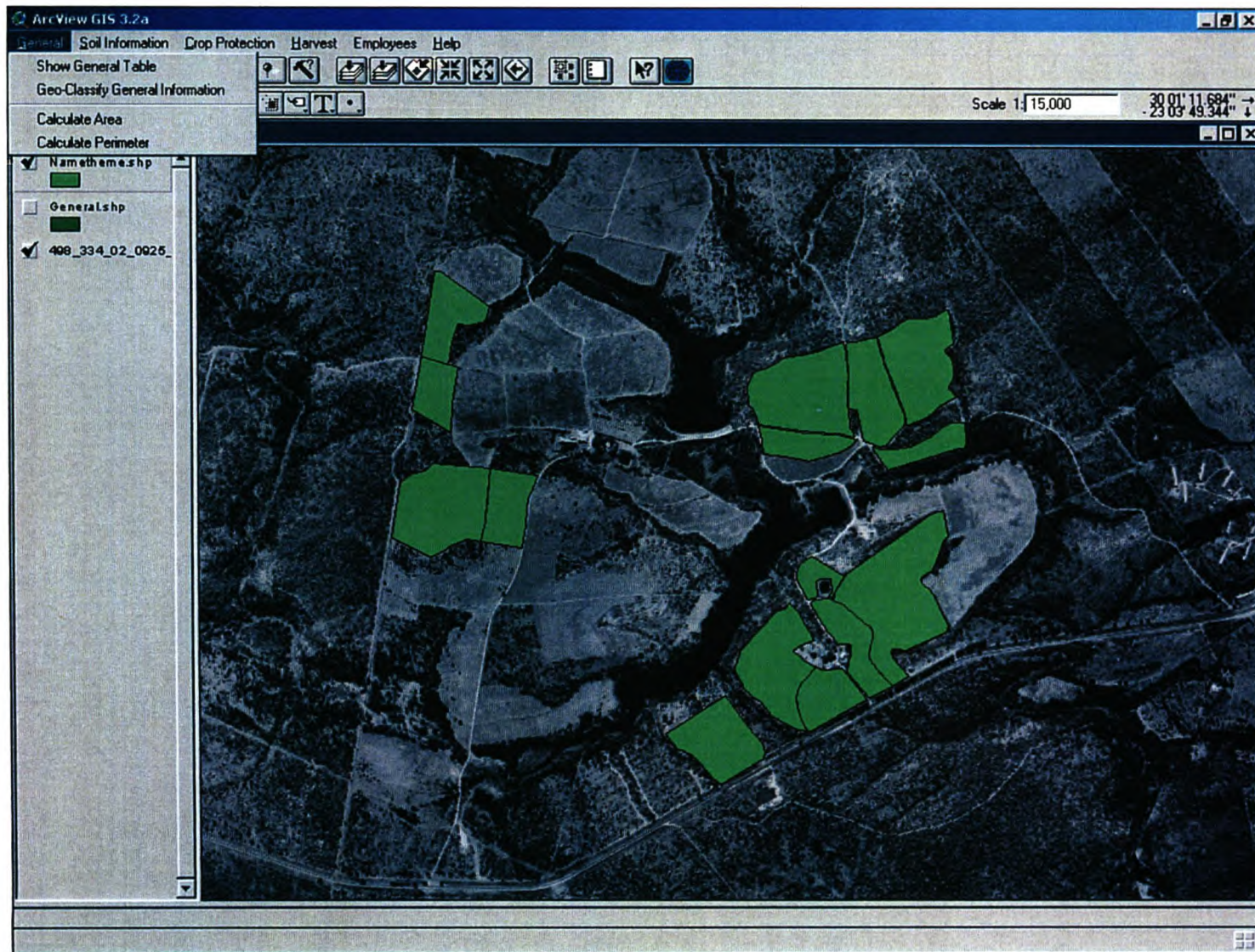


Figure 3.1 The general information menu



### 3.1.2 Geo-classify general information

The geo-classify function utilizes the ArcView table of contents to thematically classify features in the general table. When this item is selected, three options are made available to the user, allowing map classification according to variety, number of trees and plant density. A map classified according to variety creates a unique value map, where each variety is displayed using a different colour. Figure 3.2 illustrates the use of a unique value map to display the different varieties for Nooitgedacht. Graduated colour maps are used to portray the number of trees and plant density for the different orchards. Graduated colour maps represent features with a colour ramp, where increasing numerical values are displayed by increasing shades, as shown in Figure 3.3. Users are also allowed to restore the theme to be displayed as a single symbol.

Although graduated symbol maps would have been more suitable to portray data such as number of trees and plant density, ArcView does not allow graduated symbol maps to be created for polygon features. To overcome this problem, the polygon centres for the different orchards were calculated as  $x, y$  coordinate pairs, and added as two fields to the general table. An event theme were added to the project making use of the polygon centres, which rendered a point theme representing the different orchards. This point theme was used to create a graduated symbol map for the number of trees as well as the plant density. Figure 3.4 illustrates the use of a graduated symbol map to display the number of trees for each orchard. It was felt, however, that graduated colour maps allowed a better visual representation of the data, especially when the intended users (farmers) are taken into consideration, and therefore this method was preferred for map output.

### 3.1.3 Calculate area

This function determines the area, in hectares, for all orchards or a selection of orchards, as specified by the user. When this function is performed, the general table is checked and a column for area information is created if one does not exist. Area information is crucial in determining fertilizer application, and is useful when production analysis is done.



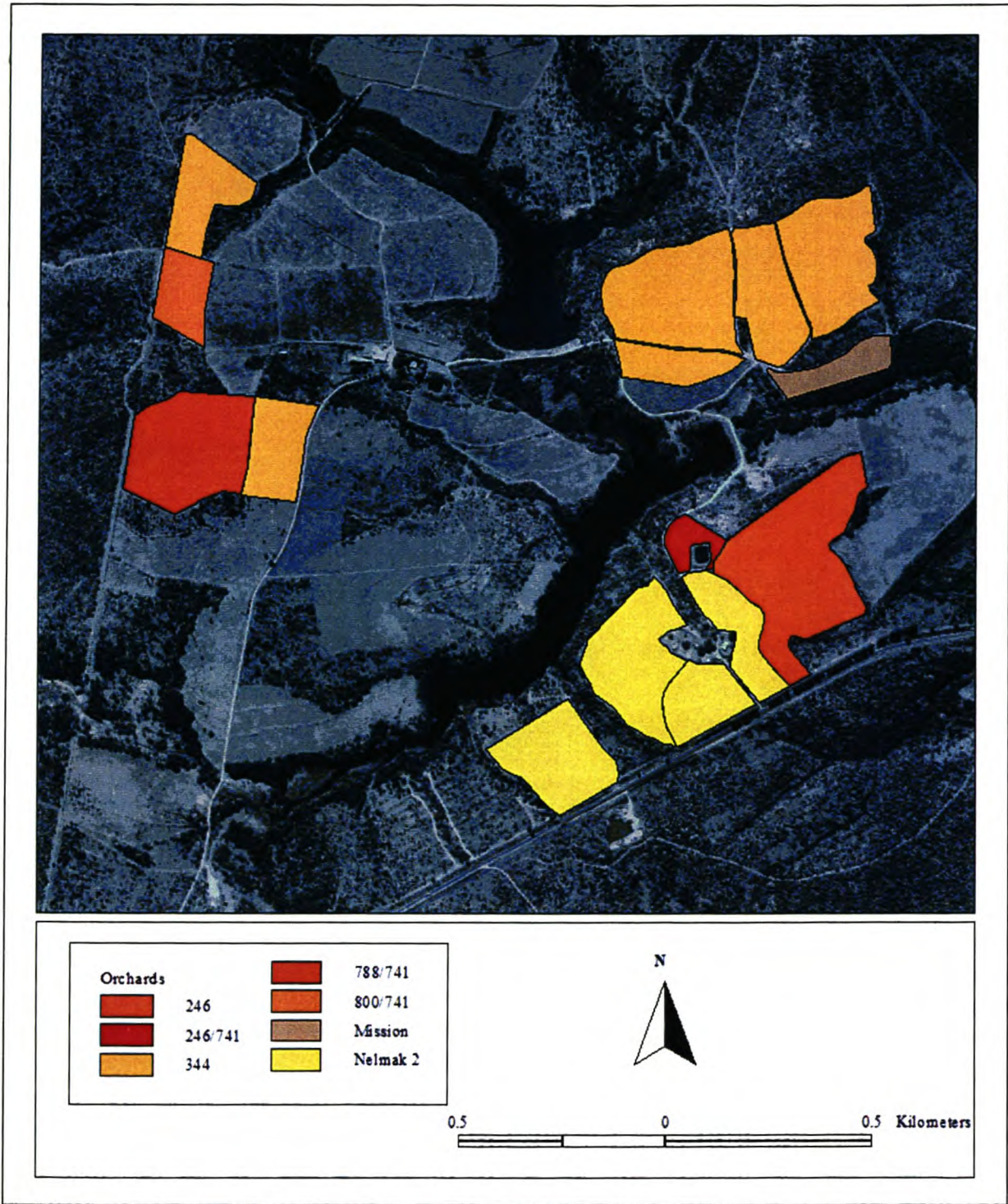


Figure 3.2 Orchards classified according to variety



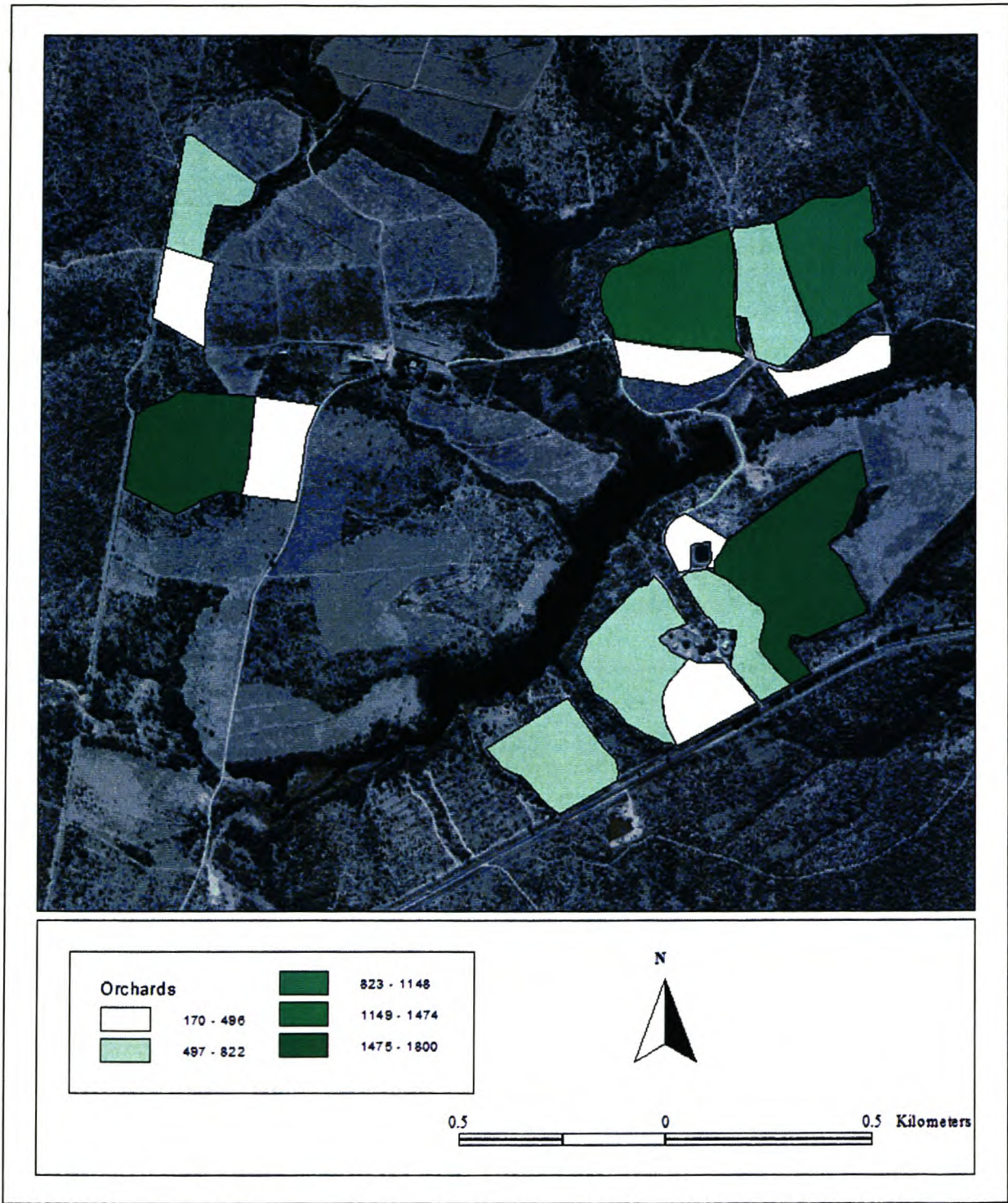
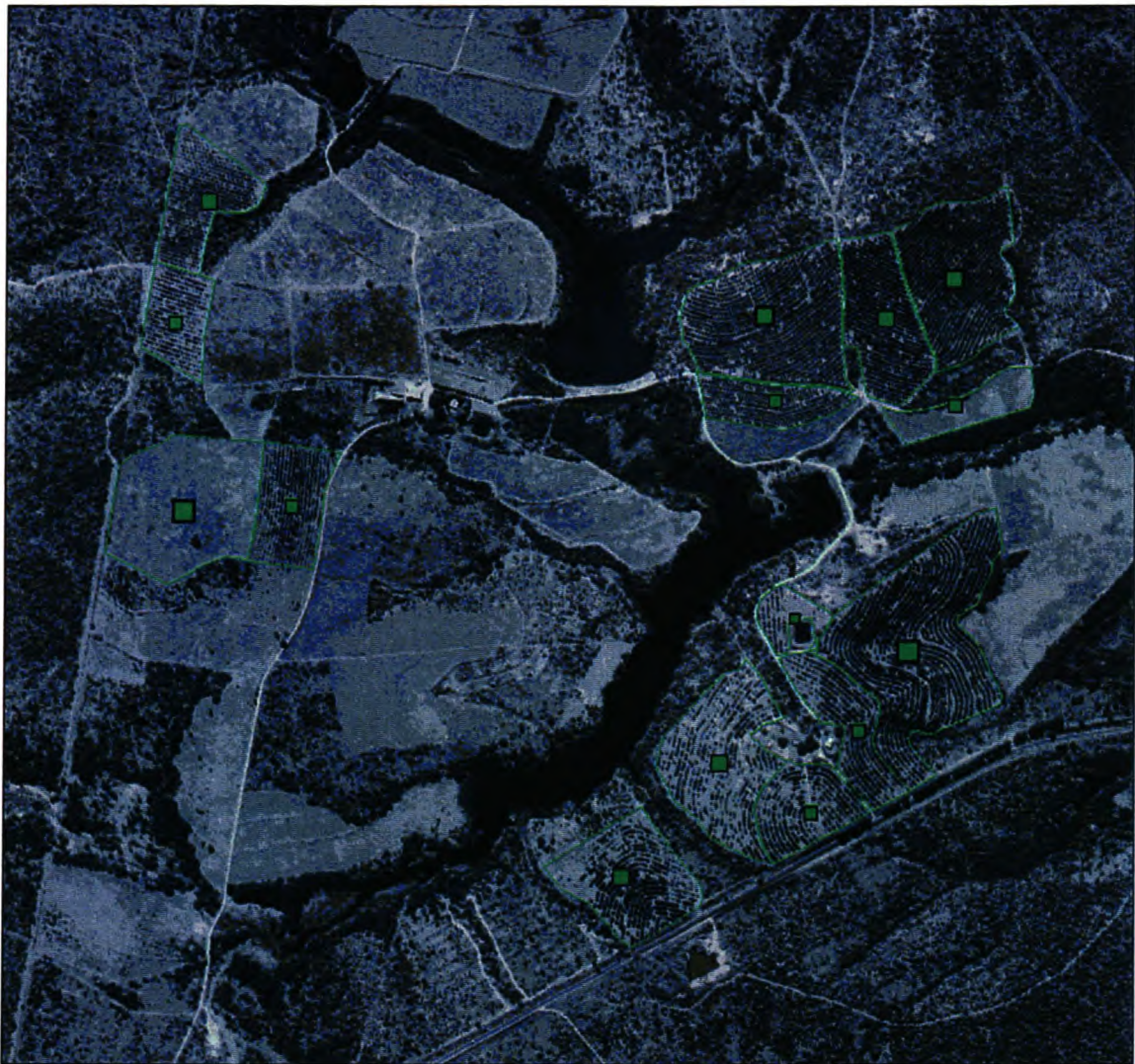


Figure 3.3 Orchards classified according to number of trees





Orchards	
■	> 170
■	171 - 520
■	521 - 790
■	791 - 1300
■	1301 - 1800



Figure 3.4 Graduated symbol map representing trees per orchard



#### 3.1.4 Calculate perimeter

Determines the perimeter, in meters, for all orchards or for a selection of orchards. Perimeter information is useful when estimating material needed for erecting fences, and was added to the project to add functionality. If no field for perimeter information is found in the general table, ArcView updates the table by adding a new perimeter field.

### 3.2 SOIL INFORMATION

The soil information menu (Figure 3.5) provides access to functions related to soil (nutrient) analysis and the application of fertilizers. The soil information menu contains ten functions.

#### 3.2.1 Show soil analysis table

Displays the table containing information on soil nutrient content. The table is displayed as a table document, allowing data to be added, edited and deleted.

#### 3.2.2 Update soil analysis table

This function updates the soil analysis table after nutrient analyses have been performed on the different orchards. The user is prompted to enter the date of analysis. The soil analysis tables are checked for an existing entry in the given the year and the action is aborted if an entry exists, since nutrient analysis are performed annually. If no existing data is found, a new table is created for the year specified. A dialog box<sup>3</sup> prompts the user for information on the analysing facility, soil pH, and the respective values for phosphorus, potassium, calcium, magnesium and sodium. The values suggested in the soil analysis are indicated in the dialog. This action is repeated for each orchard, and the soil analysis table is updated with the new values.

#### 3.2.3 Create soil analysis graph

This function allows the user to create graphs depicting selected soil nutrient values for selected orchards. The user is prompted to make a selection of orchards if no selection

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<sup>3</sup> Dialog boxes issue messages, errors and warnings and prompt user input and selection.



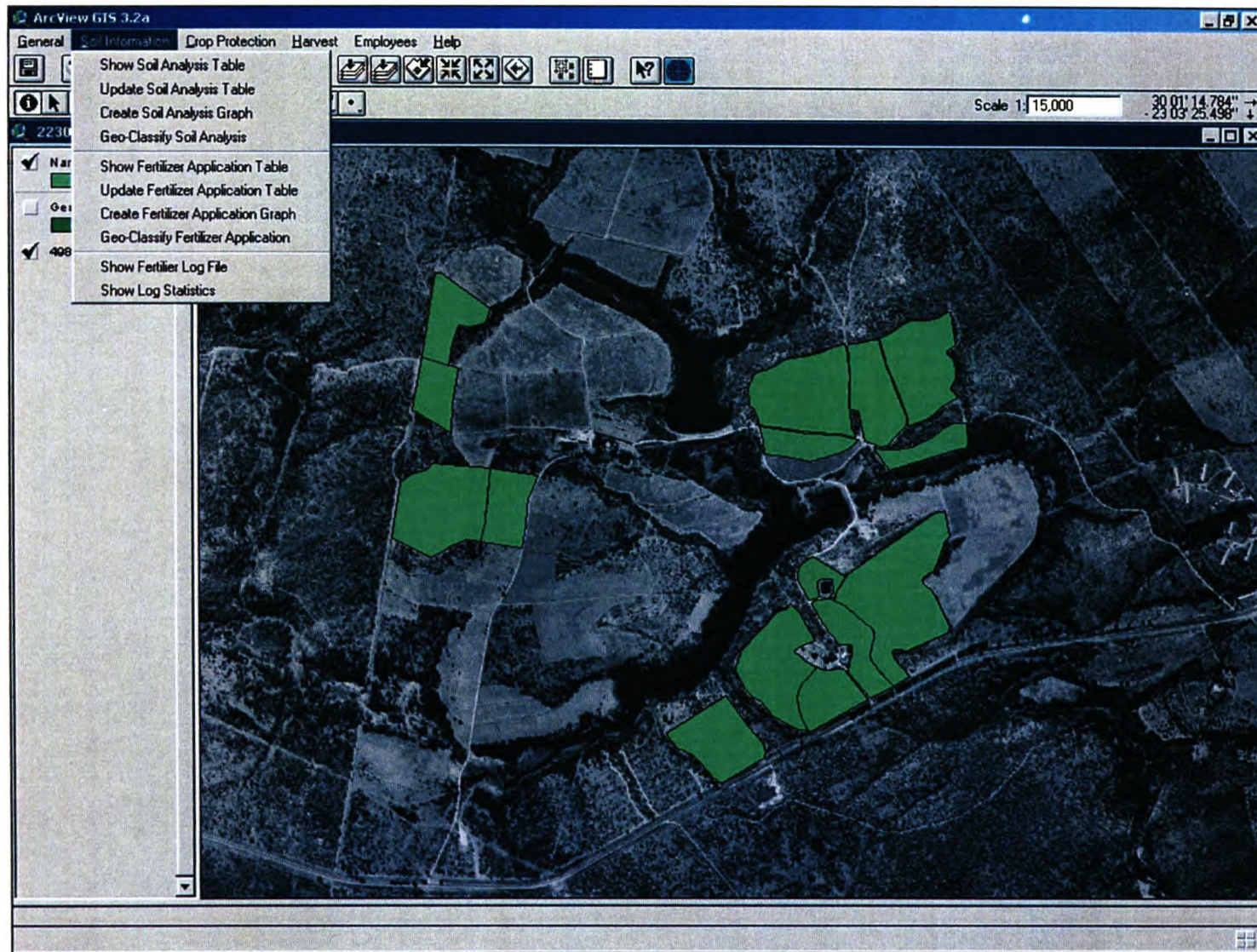


Figure 3.5 The soil information menu



exists, and are allowed to graphically display any one of the six nutrient levels tested for. ArcView creates a bar graph as a chart document, displaying the selected information for all recorded years, as displayed in Figure 3.6. The chart document allows the user to change the type of graph to a line, pie or area graph.

#### 3.2.4 Geo-classify soil analysis

The geo-classify soil analysis function creates a graduated colour map based either on soil pH or the respective concentration values of the phosphorus, potassium, calcium, magnesium or sodium levels of the soil. A dialog box allows the user to select the appropriate classifier, as well as the year to be used for classification. ArcView uses standard deviations to classify the data by calculating the mean value and placing intervals at one standard deviation increments above and below the mean.

#### 3.2.5 Show fertilizer application table

This function displays information on fertilizer application, and allows the user to add, edit and delete data.

#### 3.2.6 Update fertilizer application table

The update fertilizer application table function allows the user to update records on fertilizer application for the farm as a whole or for a selection of orchards. The user enters the date of the application via dialog box. The method of application (grams per tree or tons per hectare) is selected, and the user is prompted to enter the amount of fertilizer used (kg dry weight). A list of registered products allows the user to select the fertilizer applied, while the operator tasked with the application is selected from a list (only accredited employees are added to this list by referencing the employee details). The user also provides the method of application.

ArcView calculates the applied mass of each nutrient applied by referencing the fertilizer description table as well as the area of the orchard or the number of trees. The fertilizer application table is updated with the relevant values. ArcView also updates an orchard-

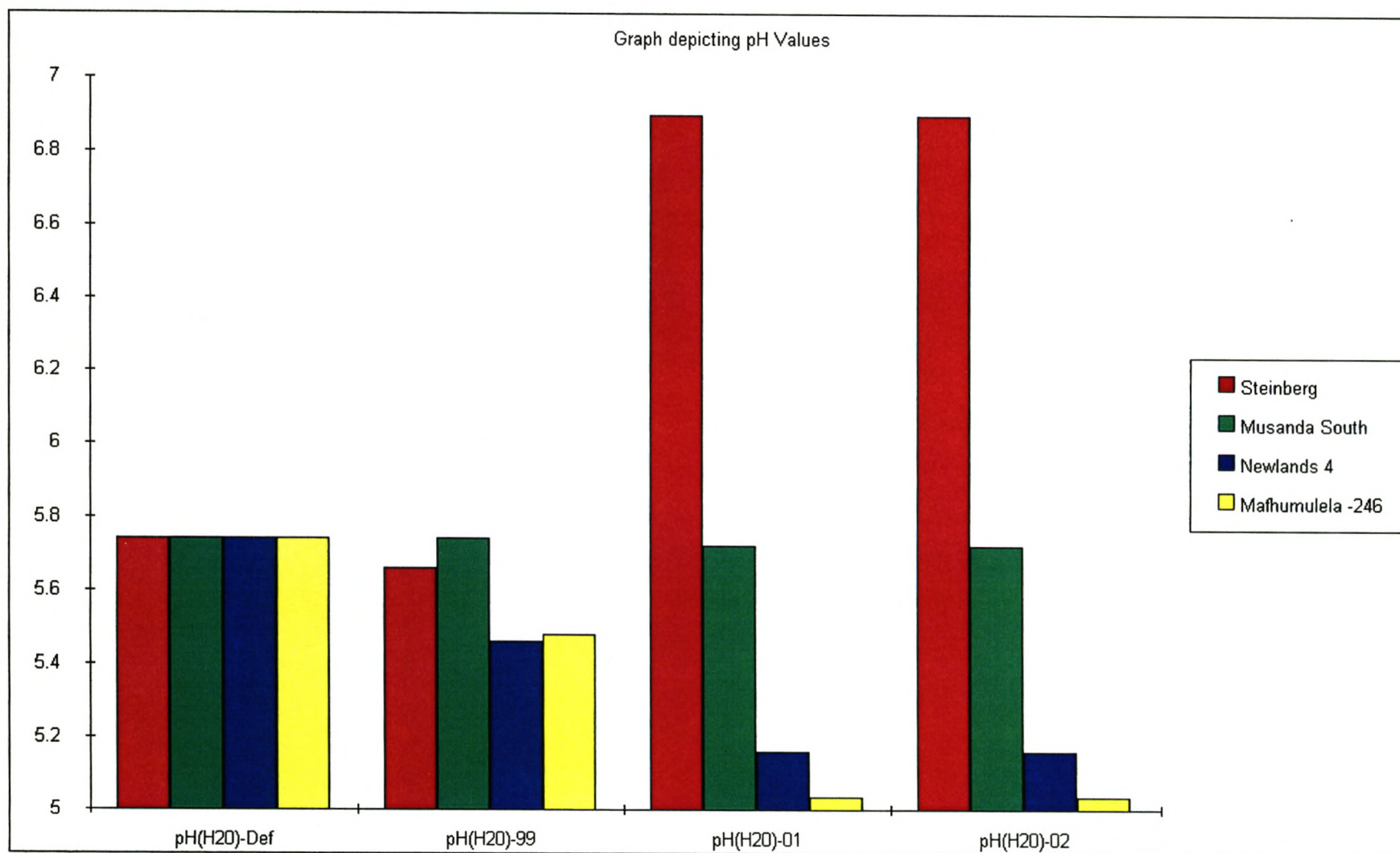


Figure 3.6 pH Values for selected orchards



specific log file with the date, type of fertilizer, applied mass, method of application and operator name.

### 3.2.7 Create fertilizer application graph

This function allows the user to create a graph depicting the application of nitrogen, phosphorus, potassium, calcium, magnesium and sodium. The user is prompted to make a selection of orchards, and to select the appropriate classifier from a list. ArcView creates a bar graph as chart document that allows the user to change the type of graph to a line or pie graph.

### 3.2.8 Geo-classify fertilizer application

The geo-classify fertilizer application function creates a graduated colour map based on the application of nutrients. The user is prompted to select the nutrient for classification, as well as the year and number of the application. ArcView divides the range of attribute values into five equal sized sub-regions. The data can then be normalized by the area of the orchard or the number of trees, which will depict the amount of each nutrient applied per unit.

### 3.2.9 Show fertilizer log file

This function displays a table containing information on date, fertilizer used, amount dry weight, method of application and operator on all previous fertilizer applications. The user selects the orchard under investigation from a list if there is no current orchard selection.

### 3.2.10 Calculate statistics

This function creates an on-screen report of the amount (kg dry weight) of each fertilizer used. It also provides the user with a summary on the amount of fertilizer used most, the amount of fertilizer used least and the product most frequently used.



### 3.3 CROP PROTECTION

The crop protection menu, shown in Figure 3.7, contains ten functions that focus on pest observation and actions taken to reduce pests to economically acceptable levels.

#### 3.3.1 Show registered products

Displays a table containing information on pesticides, herbicides and fungicides registered for use in South Africa and the European Union. Information on the type and formulation of the product, as well as the recommended pre-harvest interval is included in the table. Users are allowed to add, edit and delete data in this table.

There are currently no fungicides registered for use on macadamias in South Africa, and for this reason herbicides and fungicides were not included in this list. Since the control of weeds and diseases are normally done on a preventative basis, a table similar to the one used for pesticides can be created for fungicides and herbicides, but the internal structure may vary.

#### 3.3.2 Update product list

This function prompts the user to add new entries to the list of registered pesticides, edit existing entries and to delete products from the list, since the list of registered pesticides changes on a regular basis.

#### 3.3.3 Show scout information table

This function displays the results of pest analysis that have been performed. The user is prompted to select the pest for which information is needed from a list. ArcView retrieves the table containing information on the selected pest, and joins it to a table containing orchard information. The tables are separated when the window is closed.

#### 3.3.4 Update scout information table

Updates the information on the occurrence of a specified pest, as selected by the user. The user supplies the date that the scout has been performed. ArcView ensures that data for the specified pest and date does not exist, and prompts the user to enter the measured



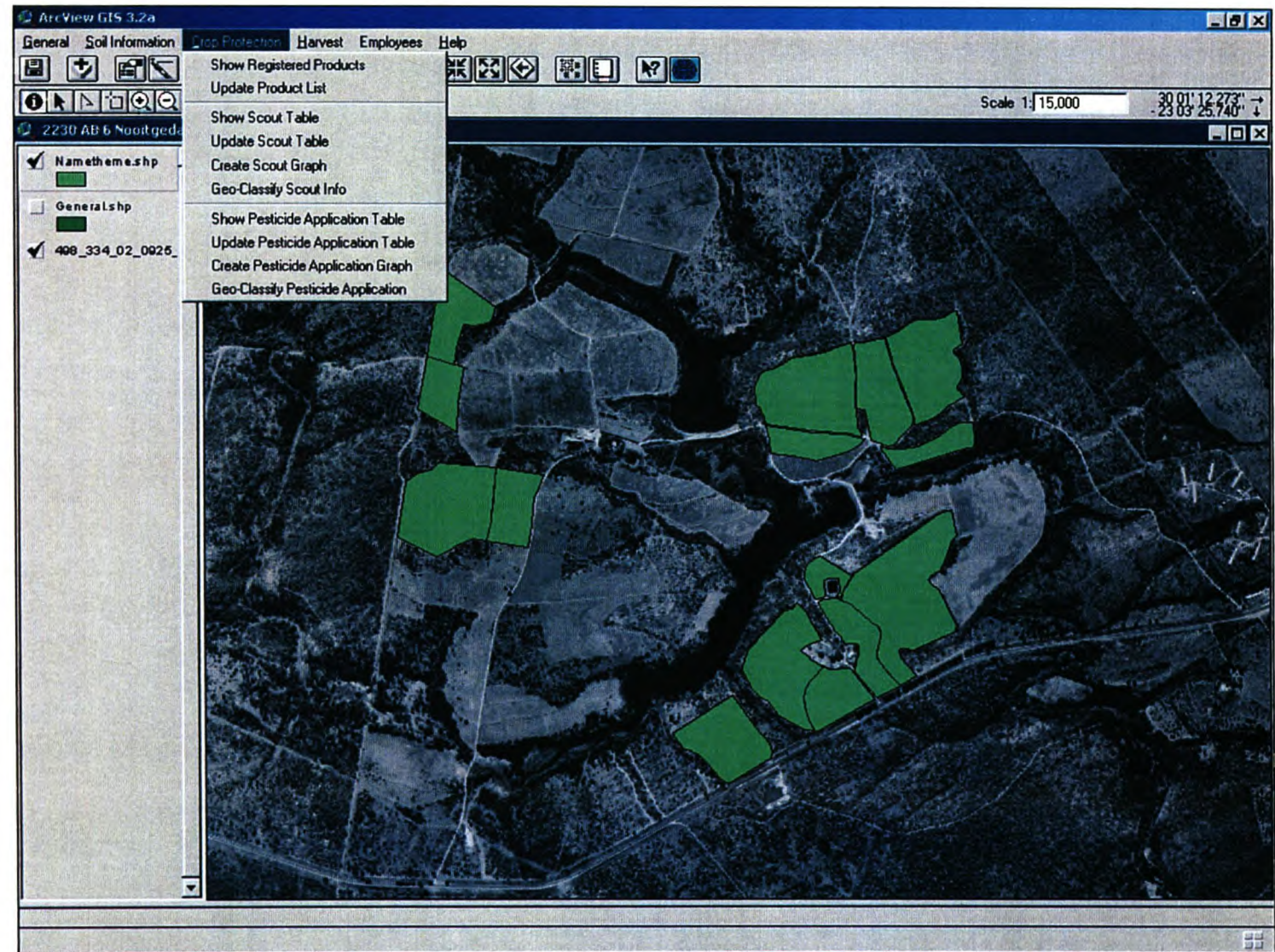


Figure 3.7 The crop protection menu



value for each orchard. The scout table is updated by adding a column that is uniquely identified by the date that the scout has been performed.

### 3.3.5 Create scout graph

This function creates a graph of monthly pest occurrences for a selection of orchards, based on data in the scout table for the pest selected by the user. ArcView creates a bar chart displaying pest fluctuation over time. The graph is created as a chart document that allows the user to change the chart style.

### 3.3.6 Geo-classify scout information

Creates a graduated colour map of pest occurrence per orchard for a specified date. The user selects the pest under investigation and specifies a date. Since the range of values scouted will vary after each scout session, the classification range needs to be standardized in order to allow comparison. To achieve this, the software determines the minimum and maximum scout value in the table, by analysing all scout sessions for all years. Based on this absolute minimum and maximum values, a range can be calculated that will be representative for all the data. By dividing this range into five equal intervals, and classifying the data for the chosen year accordingly, comparisons between different dates become possible.

The scout data for stinkbugs will be used as an example. The minimum value scouted was two (in July 2002), while the maximum (14) was scouted in August 2002. Figures 3.8 and 3.9 shows the classification of orchards according to this range for the two dates (July and August 2002). Variation from one date to the following becomes clear.

### 3.3.7 Show pesticide application table

Shows information on pesticide application per orchard for a specific pest, as identified by the user.

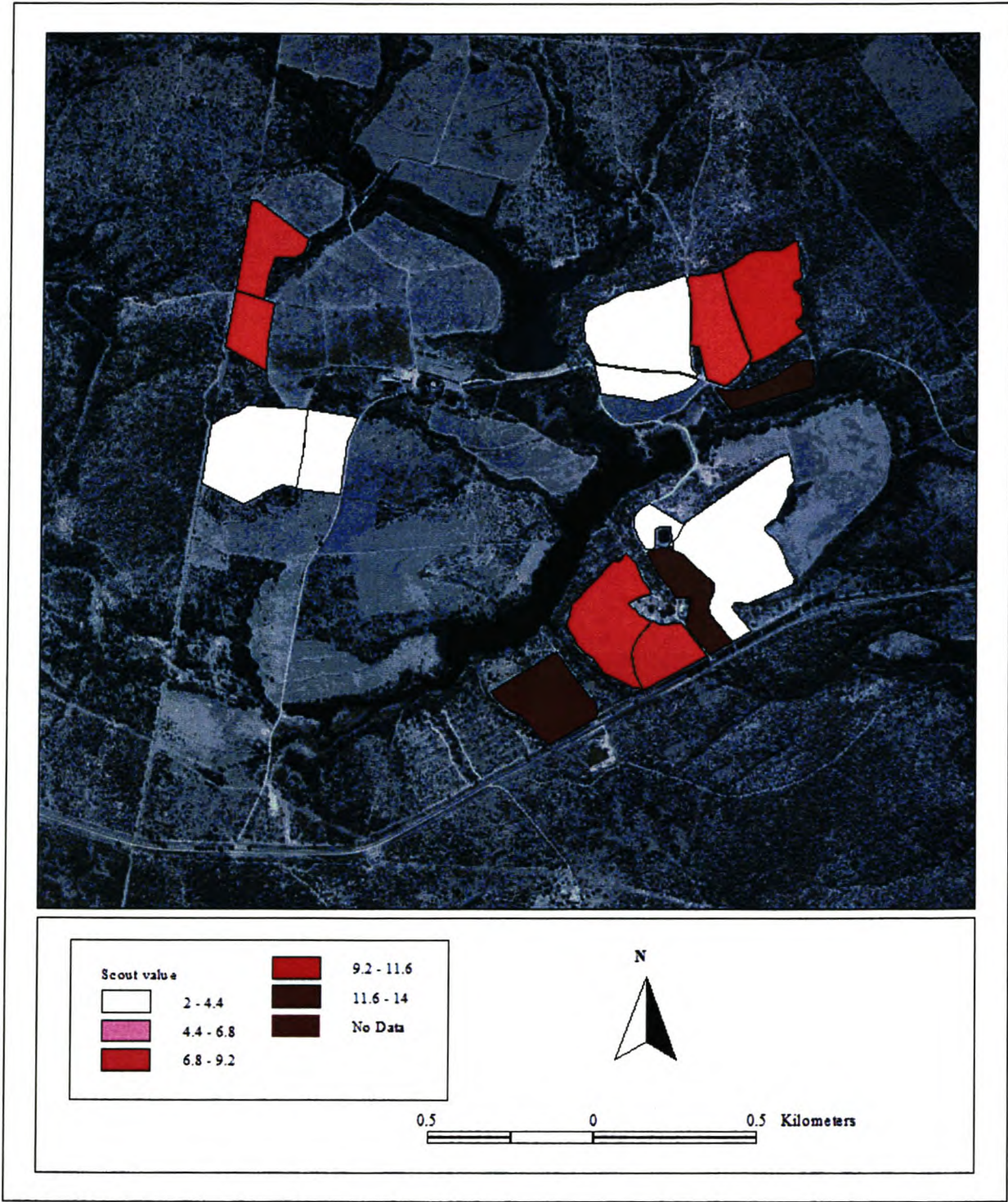


Figure 3.8 Orchards classified according to number of Stinkbugs (July 2002)



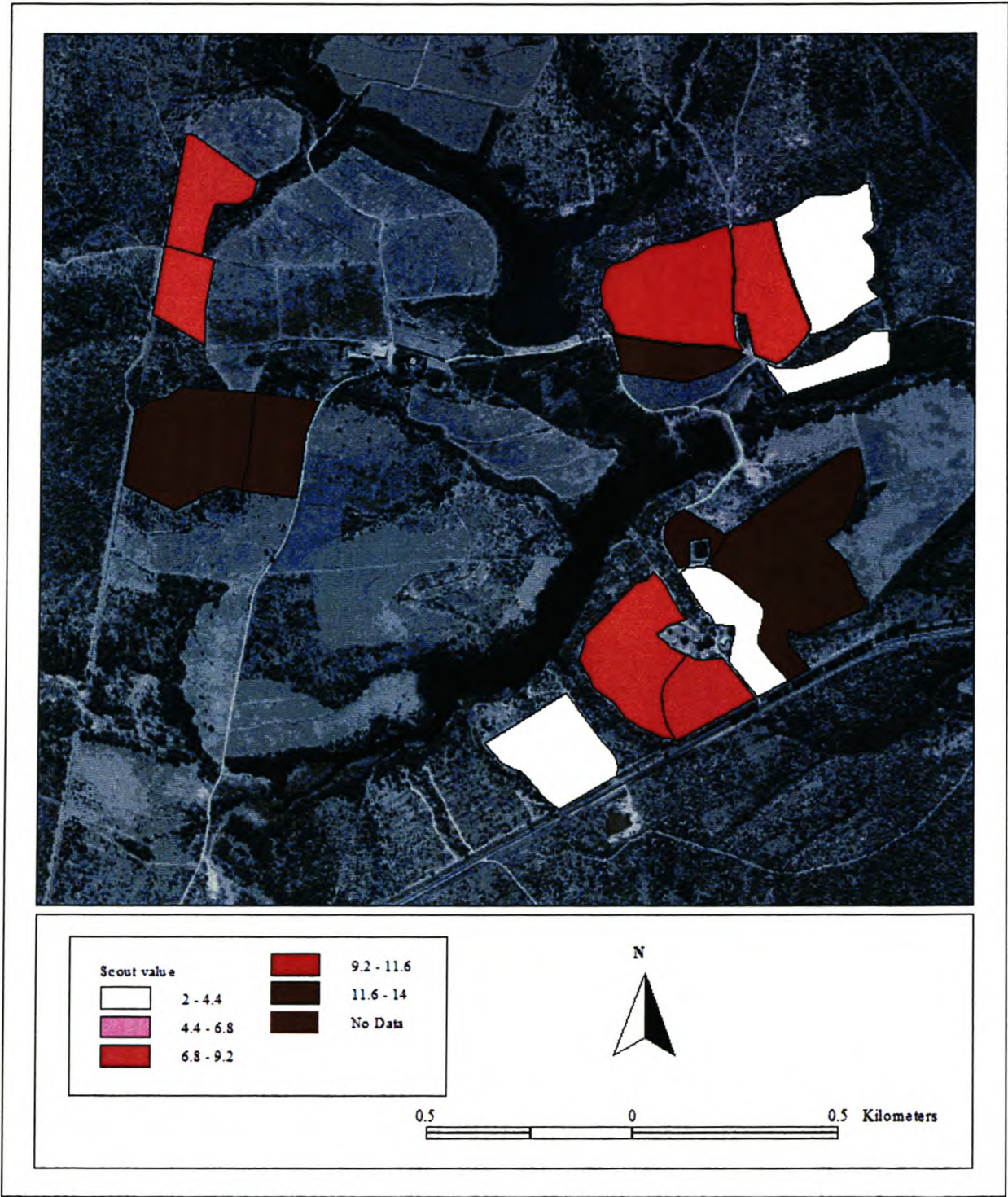


Figure 3.9 Orchards classified according to number of Stinkbugs (August 2002)

### 3.3.8 Update pesticide application table

Updates information on the application of pesticides for a specific pest, which the user selects from a list. The user enters the date of application. The function is aborted if data for the date specified exists, or if no scout for the date specified has been performed. The user is prompted to select the product used from a list. Only products registered for use on the pest specified is added to the list. The user is prompted to enter the amount of pesticide applied for each orchard. A warning is given when the scout value for a specified orchard does not exceed the pest threshold value.

### 3.3.9 Create pesticide application graph

Creates a bar graph of the application of a product for a specific pest, as specified by the user. The graph is created as a chart document, which allows the user to change the style.

### 3.3.10 Geo-classify pesticide application

Creates a graduated colour map of pesticide application per orchard for a specified date. The pest under investigation, as well as the date, is selected from a list. The quantity of pesticide that is applied is determined by the size of the trees (litres per tree). Orchards are classified into five groups, dependent on the amount of pesticide used, calculated as litres per tree multiplied by the number of trees in the orchard.

An alternative method for classification that can be used is a Boolean (TRUE/FALSE) classification, where orchards can either be classified as treated (when the amount of pesticide is greater than zero) or not treated (when the amount of pesticide is equal to zero) on a specific date. This classification type was not used in this study.

## 3.4 HARVEST INFORMATION

The harvest information menu (Figure 3.10) contains five functions aimed at analysing annual production.



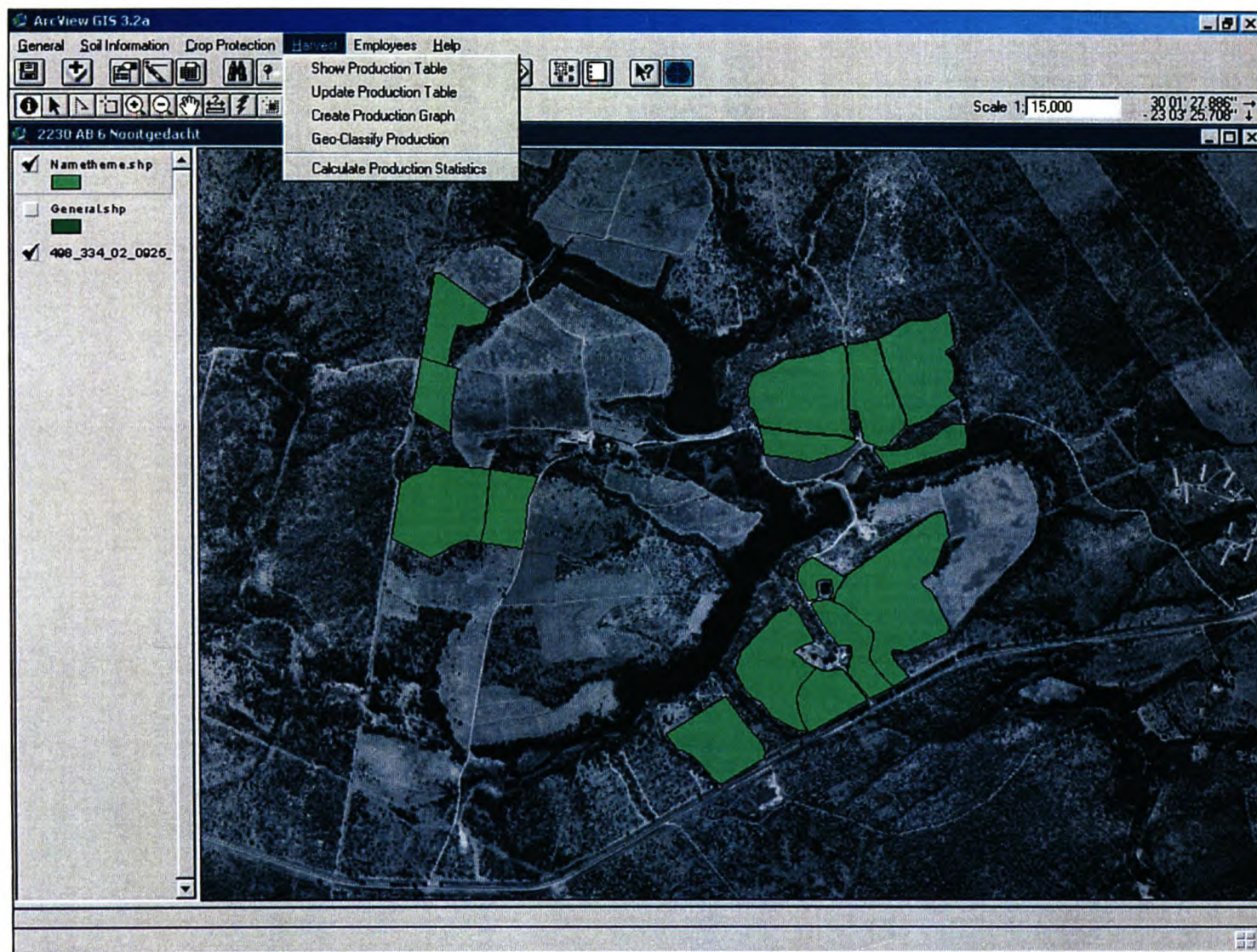


Figure 3.10 The harvest information menu



#### 3.4.1 Show production table

This function displays the production (in kilograms) per month for each orchard in tabular format as a table document. The user enters the year under investigation and selects a month from a list.

#### 3.4.2 Update production table

The update production table function allows the user to add, delete and update information in the production tables. The user is prompted to enter the year and month of production. If data for the given period exists, new data entered are added to the existing data. If no data exists for the given year or month, a new table is created, and data for each orchard is entered individually.

#### 3.4.3 Create production graph

This function creates a graph displaying either monthly or annual production per orchard for a selection of orchards, and the user is prompted to make a selection if none exists. The graph is created as a chart document, allowing the user to change the type (from the default bar graph) to a line or pie graph.

#### 3.4.4 Geo-classify production

The geo-classify production function creates a graduated colour map based on production (in kilogram) per orchard. The user is prompted to select the year and month on which the classification is based. ArcView divides the data into five intervals of equal size. Data can be normalized by the area of the orchard or the number of trees in each orchard, by referencing the general information table. The normalization will produce a map depicting production per hectare or production per tree, allowing orchards to be analysed according to the same standard. Figures 3.11 shows a production map that has not been normalized, while Figure 3.12 depicts a normalized production map.

#### 3.4.5 Calculate production statistics

This function prompts the user to select a year. Four onscreen reports are displayed with information on the following:



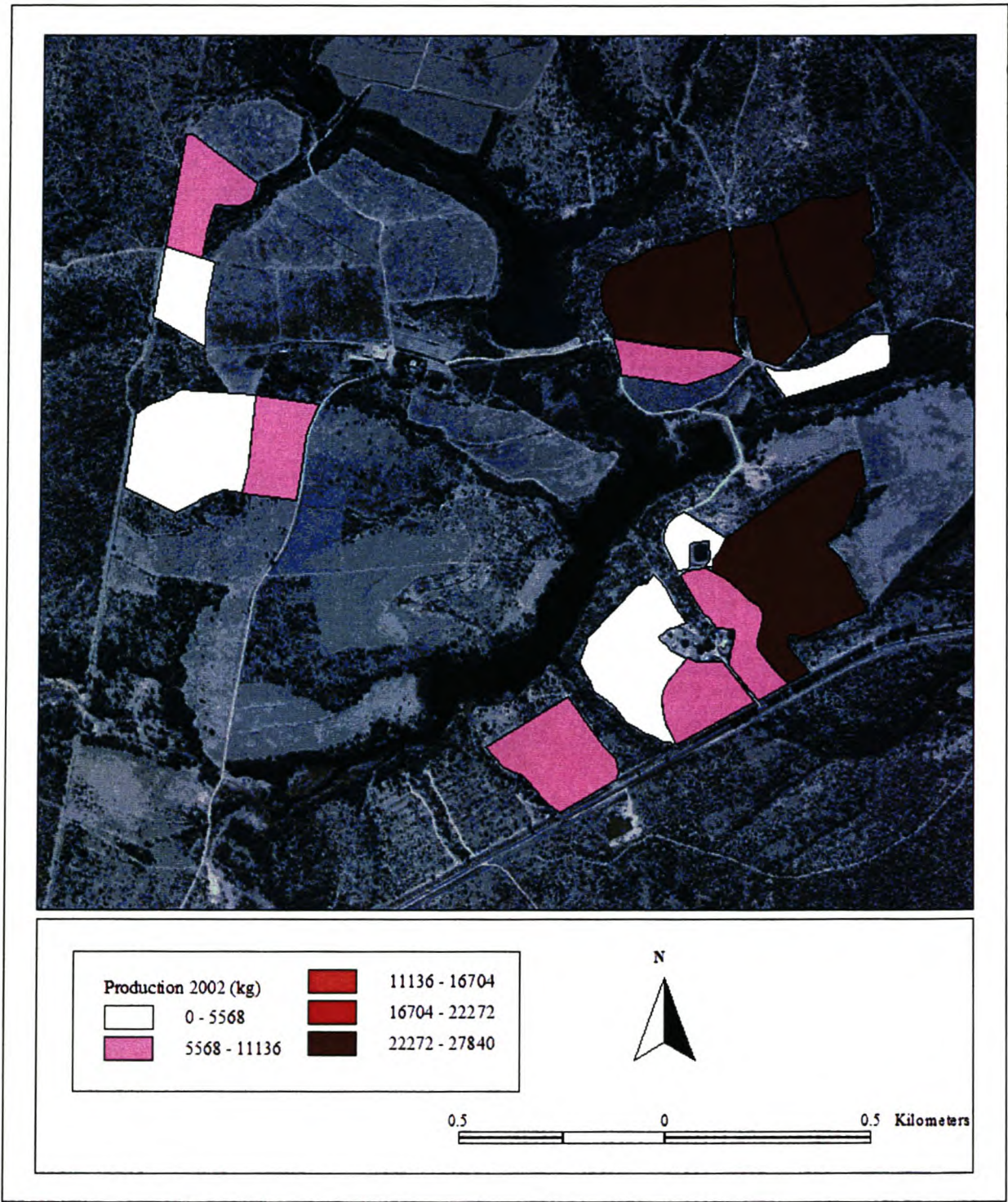


Figure 3.11 Production per orchard (kg) in 2002



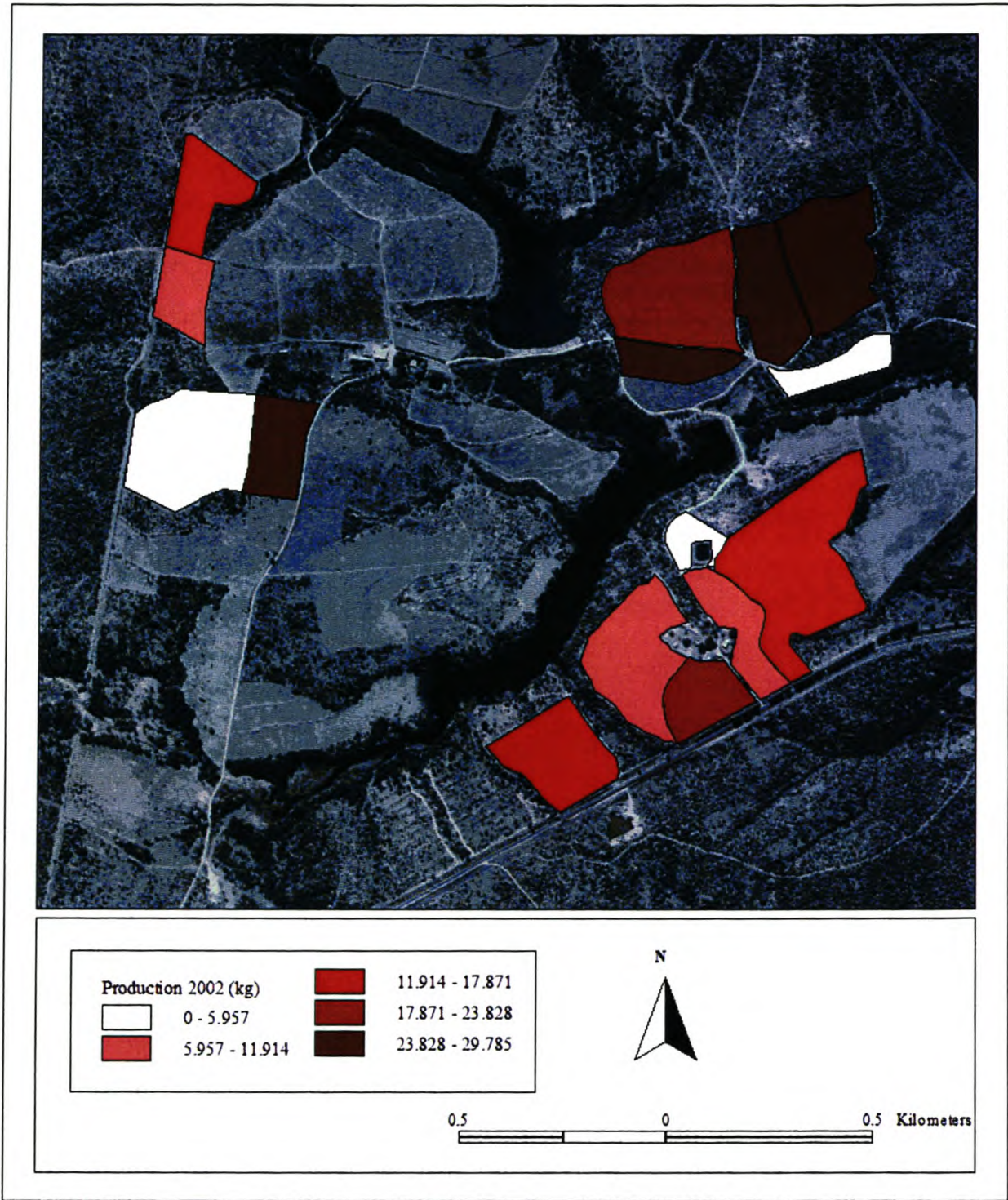


Figure 3.12 Production per tree (kg/tree) in 2002



- Total production per year
- Production as a percentage of the previous year's production
- Production per hectare
- Production per tree
- Total production per variety
- Production per hectare for each variety
- Production per tree for each variety

### **3.5 EMPLOYEE INFORMATION**

The employee information menu (Figure 3.13) contains two functions used to record data on personnel.

#### **3.5.1 Show employee details**

This function displays the table containing all the information on employees as a table document.

#### **3.5.2 Update employee details**

This function prompts the user to create an entry for a new employee, or to update the particulars of an existing employee.

This chapter discussed the customisation of a new ArcView project to allow the analysis of GAP specific data. Data analysed were represented in tabular, graphical and geographical format, as well as by the use of on-screen reports. It now becomes important to determine the potential of these outputs to aid in the decision making process. In Chapter 4, an evaluation of the database and the outputs received from the project will be made.

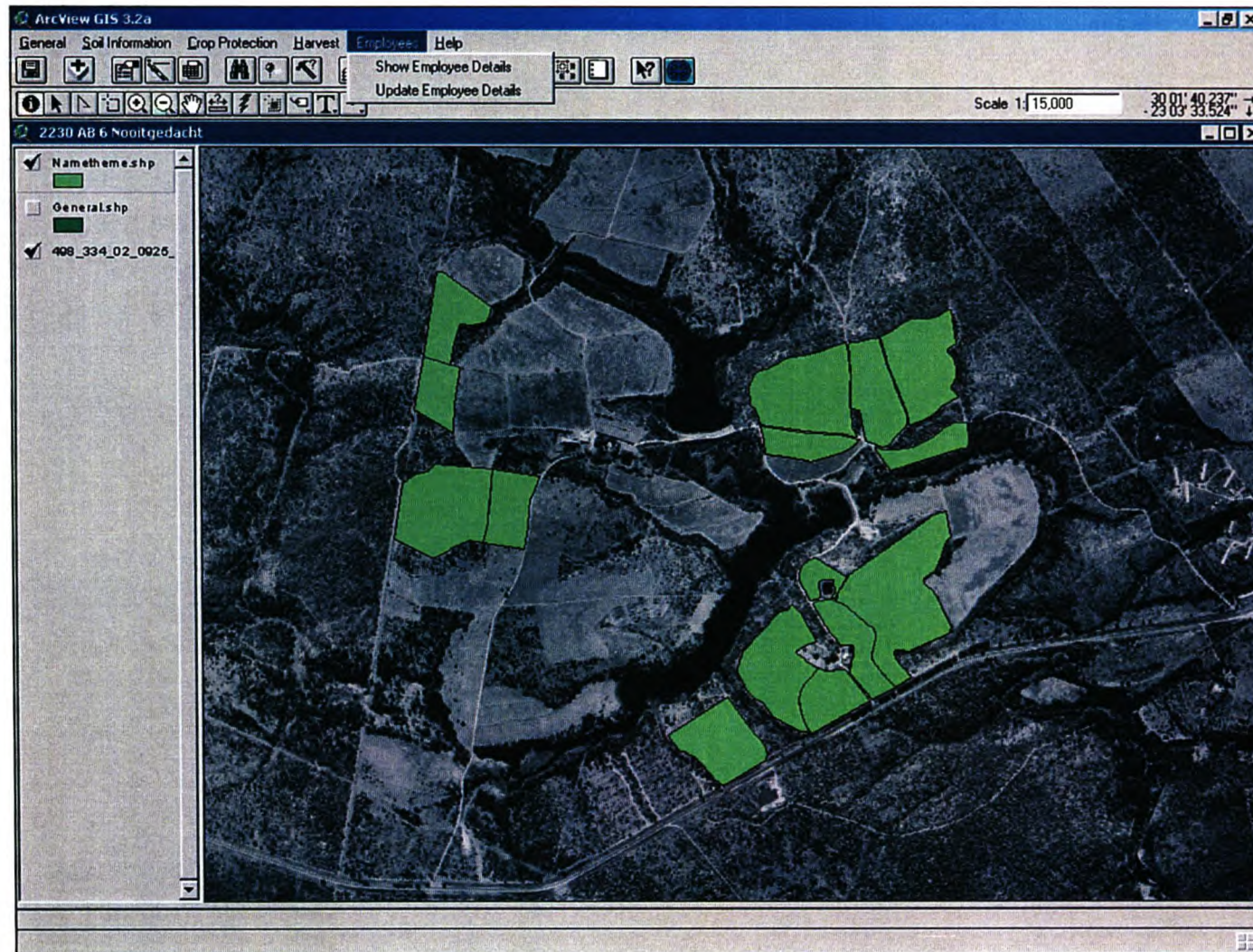


Figure 3.13 The employee information menu



## **CHAPTER 4**

### **EVALUATION OF THE PROJECT**

Food safety is a global issue that is not contained by international boundaries. The goals of good agricultural practices are to reduce the risks of food safety lapses in agricultural production through the systematic implementation of the best possible farming techniques. The implementation of such techniques depends on a process of decision-making, which is dependent on the availability of accurate and timely information. Drost et al (1996) mentioned that “the adoption of sustainable farming practices are often hampered...by the lack of up to date information”. By designing a database that encompasses relevant data, as discussed in the previous chapter, and then processing this data, the interaction between different related farming attributes could be computed and displayed. Having data available in electronic format and receiving output in tabular, graphical and geographical format in near real-time should then aid in the decision making process, and ultimately in implementing good agricultural practices.

In Section 1.2 on page 3 it was stated that the objective of this study was to establish a computerized record keeping system that would aid the implementation of GAP accreditation by:

- Determining the kind of data needed to establish a database
- How the data should be structured in the database
- How the data could be displayed graphically
- How the data could be represented geographically
- How the data could be displayed in tabular format
- How interaction between various data types could be established

This chapter will discuss the perceived effectiveness of the database structure and the queries that were implemented in terms of GAP requirements. The significance of the output will be discussed, as well as the value of this project to the farm manager as a tool for decision making and planning.

## 4.1 PROJECT EVALUATION ACCORDING TO GAP COMPLIANCE CRITERIA

The EurepGAP control points and compliance criteria document was designed in the form of a checklist and specifies the required and recommended criteria for GAP status accreditation. For the purpose of this study some of the various categories of the EurepGAP general regulations document was used as a template in the design of the database. By making reference to the control points and compliance criteria, the database can be evaluated according to category (Appendix C). Compliance of the database to both required and recommended criteria will be discussed for each category.

### 4.1.1 Varieties and Rootstocks

The control points and compliance criteria for varieties and rootstocks were represented in the general table in the database.

- i. Choice of variety or rootstock: GAP requirements state that the choice of variety needs to be agreed with the customer. All orchards in the study area were established before this ruling came into effect. This item was provided for in the database by adding a field containing a reference number to documentation (e.g. written agreement between grower and customer) with regard to customer specifications for crops grown.
- ii. Seed quality: Information on the seed quality, germination rate, variety name, batch number and seed number need to be indicated on a seed certificate. A field was included in the database to reference the seed certificate (hard copy) for each orchard.
- iii. Pest and disease resistance: Provision was made for pest and disease resistance, but a no data value was assigned in this study. This field should be populated with a reference number to written evidence such as a nursery certificate, indicating the plants' resistance to pests and diseases.



- iv. Seed treatment and dressings: Although not applicable to macadamias, provision was made for specific seed treatment during the plant rearing stage. When applicable, this field will contain a reference number to another table used to specify treatment protocols for specific pest and diseases.
- v. Nursery stock: All purchased nursery stock must be accompanied by officially recognized plant health and quality certification. This may include plant passports or terms of deliverance, as well as records of pesticide treatment applied during the plant rearing stage. The original documents should be kept as hardcopies in a file or folder, with a reference number in the database referring to these documents. A field referring to records of pesticide treatment during the plant rearing stage was included in the database.
- vi. Genetically Modified Organisms: No provision for GMO was made since it was not applicable to this study. Where applicable, a field entry for GMO can be added to the database, holding reference to hardcopies of applicable legislation documentation, as well as written agreements on the use of GMO cultivars with customers.

#### 4.1.2 Site History and Site Management

All control points and compliance criteria pertaining to site history and management were included in the general table.

- i. Site history: The first major requirement of GAP is the establishment of a recording system documenting information that refer to a surface covered by a crop, and all agronomic activities related to this surface. The main aim of this study was to fulfil this requirement. An acceptable reference system (e.g. number, colour) was needed, and therefore each orchard was provided with a unique ID. Prior use of each orchard was provided for in the table, since a risk assessment is a major requirement for the implementation of GAP.

- ii. Rotation: No provision was made for crop rotations, since it is not applicable to macadamia production. GAP requirements state that crops producing for more than one year may be excluded from this requirement. Where crop rotation is applicable, a field may be included in the database containing the next rotation date.

#### 4.1.3 Soil and Substrate Management

The soil analysis table was used for all control points and compliance criteria aimed at soil and substrate management.

- i. Soil mapping: Soil maps are not a requirement for the implementation of GAP, but are recommended for use in rotations and growing programmes. Soil maps were not prepared for this study, but could be implemented in the GIS and used with great success in fertilization and production analysis.
- ii. Soil fumigation: Soil fumigation is not applicable to macadamias. Where applicable, provision can be made in the database to reference documentation on the use of steaming, solarization, rotation and antagonist plants as alternative to chemical fumigation.
- iii. Substrates: Inert substrates are not used for the production of macadamias and therefore not included in this study. In cases where inert substrates are used, a database table can be designed containing information on location of sterilization, date of sterilization, type of chemical used, method of sterilization and name of operator.

#### 4.1.4 Fertilizer Use

The fertilizer application, fertilizer description and fertilizer log files were used for all control points and compliance criteria aimed at fertilizer application.



- i. Nutrient requirement: A soil care plan was developed by a third party consultant and is updated annually. The recommended values for all soil nutrient levels were indicated in a database table. Recommended dates and quantities of fertilizer application are provided by the consultant, based on the annual soil analysis (GAP requires a once off/seasonal calculation for single harvest crops such as macadamias). Seasonal soil analysis statistics are stored in database tables, with actual applied quantities of fertilizer in separate tables in accordance with dates specified by the consultant.
- ii. Advice on quantity and type of fertilizer: Recommendation of fertilizer application must be done by competent, qualified advisors. A field indicating the consulting party was included in the soil analysis table. This reference may also point to documentation (hardcopies) of the technical qualifications of advisors.
- iii. Records of application: All applications are recorded according to the GAP requirements. This includes reference to the geographical location of application, the date of application as well as type and mass of fertilizer used. The operator responsible for application, as well as the method used was recorded for each application and included in the database.
- iv. Timing and frequency of application: As discussed, a soil care plan and fertilizer schedule is provided annually, including nitrogen analysis and nitrogen requirement prediction for each orchard at the start of the season. The application of fertilizer is done according to this schedule, and recorded accordingly.
- v. Nitrate and phosphate levels in ground water: Nutrient requirements are calculated according to need, and application is based on crop requirements to minimize the effects of nitrates and phosphates in ground water. Analysis of ground water mineralization is recommended by GAP. Frequent nitrate and

phosphate analyses of water samples from boreholes were initiated for this study. A point theme representing boreholes was created with information on geographical location and depth. Two additional tables representing tested nitrate and phosphate levels in the water were created and linked to the borehole theme. Trends in water nitrate and phosphate level fluctuation can be determined from this.

- vi. Application machinery: GAP requires availability of maintenance records, as well as documentation on the annual calibration of application machinery. This study made no provision for records on application machinery.
- vii. Fertilizer storage: Requirements regarding fertilizer storage pertain to physical conditions under which the products are kept. The database made provision for a chemical storage table, containing information on date, product used, amount taken from store, amount returned to store, balance in store and operator responsible.

#### 4.1.5 Crop Protection

A database table was used for each pest found on macadamias, containing information on both the observation and intervention processes.

- i. Basic elements of crop protection: GAP requires written justification regarding target pests and intervention thresholds. The threshold value for each pest was included in the database. The project created requires that observation values be entered into the database before the user will be allowed to enter intervention values. The database contains a list of registered chemical intervention products, and allows only products from this list to be used in documenting actions taken towards crop protection. This study did not make provision for the use of non-chemical protection methods.



- ii. Choice of chemicals: The list of registered products includes a reference to pests for which the product is registered. Only products registered for use on a specific pest can be used when documenting intervention procedures. Various registered products for each pest were included, allowing the grower to make use of different products to avoid tolerance or resistance by pests. Changes to the list of registered products can be made by the grower/user to incorporate changes in pesticide legislation. Substances banned in the European Union were indicated as such, and the project does not allow the use of such products to be recorded.
- iii. Records of application: Documentation on pesticide application includes the name and variety of the crop treated, the exact geographical location of treatment, name and amount of product used, the date of application and the name of the responsible operator, all in accordance with GAP requirements. Justification of pesticide application is done by referring to the pest treated for and the threshold and observed values of this pest for each orchard. Provision was not made to reference the person responsible for the pesticide recommendation, but can be included in the database.

#### 4.1.6 Harvesting

The GAP document addresses worker hygiene and packaging requirements under the topic of harvesting. This study did not address the aforementioned issues, since they are of a nature requiring practical implementation, with little or no benefit from detailed record keeping. Detailed records, acquiring data on a daily basis, were developed allowing the grower to monitor crop production trends and statistics.

#### 4.1.7 Worker Health, Safety and Welfare

As is the case with harvesting, worker health, safety and welfare require practical implementation measures. This study developed a complete recording system, holding

all details regarding employees. GAP requirements such as proficiency in medical aid and the handling of chemicals were included in the database. All other data regarding employees are used by the farmer for daily operations.

In the previous section it was shown that the project, as customised for this study, addressed the majority of issues required for the implementation of GAP status on farms. Section 4.2 focuses on the significance of the study to the farmer, apart from a GAP perspective, with reference being made to the various formats of data output.

## **4.2 SIGNIFICANCE OF THE STUDY TO THE FARMER**

Effective farm management depends on the effective planning of activities and sound decision making. The processes of planning and decision-making are dependent on quality and timely information. The project developed for this study simplifies the record keeping process on farms. Users are allowed to capture daily activities such as pest monitoring and control, fertilization practices and harvesting with a minimum amount of time and duplication, while records on production and employees are kept up to date. The data captured may then be represented in geographical, graphical, tabular and text format at a later stage to allow analysis.

Data in geographical format allows the user to visually interpret events prevalent on different areas of the farm, whilst functions such as normalization allow data from different areas to be compared side by side. With data in tabular and graphical format, analysis of historical events and conditions becomes possible, while trends (from graphs) can be used to do simple forecasting. Statistical data in report format also aid in analysing trends and forecasting events, while it may also prove to be useful in budget and procurement activities.



## **CHAPTER 5**

### **CONCLUSIONS AND RECOMMENDATIONS**

To ensure a continuation of exports of local products to international markets, South African farmers are being forced to adapt to international standards, such as Good Agricultural Practices, which is based on the principles of good record keeping. Good record keeping provide a means of identifying and implementing best farming practices, thus enabling growers to assure customers that food safety and quality requirements have been met. The aim of this study was to design a record keeping system, based on GIS technology, that complies with EurepGAP requirements, and that aids in decision making for GAP and precision farming. ArcView GIS was used to implement the database and to allow user interaction with the data.

Spatial data such as soil analysis, fertilization, crop protection and production were incorporated into a database, all in accordance with GAP requirements. Customisation of the GIS software allowed this data to be coupled with other relevant data sources such as static orchard information and employee records. Various functions were created to allow the database to be updated and analysed.

By constantly updating the database, the farmer has better control over the various farming activities and therefore ensures improved farm management through better planning. Analysis of the database explored relationships between the different data sets and output was given in geographical format (as thematic maps), tabular format, graphical format (as line, bar or pie graphs), as well as in the form of written reports.

With output given in the aforementioned formats, the user is allowed to visually interpret current farm conditions and to analyse trends in the data. As the database expands, the said relationships and trends will become more meaningful. When used in conjunction with data such as soil maps, hydrological and climatological data, historic trends may become useful in forecasting events.

“The application of GIS is only limited by the imagination of those who use it” (Dangermond, 1996). This remark from Jack Dangermond, president of ESRI, emphasizes the scope for continued refinement of a project such as the one created in this study. By incorporating more natural factors that affect agriculture such as climatological data (rainfall and temperature), irrigation schemes, the leaching of soil nutrients, surface runoff and chemical pollution (point source and non-point source), detailed spatial models of processes pertaining to crop production can be created. Such models can then be used in predicting certain outcomes e.g. the effectiveness of fertilization and crop protection, and the effect that these factors have on production.

Latitude, longitude and height above sea level affect the production capabilities of different varieties of agricultural crops. A farm planning and layout module included in a GIS-based farm management project could advise farmers on the most suitable variety to be used, based on local conditions, thereby ensuring best practice. Varieties that are more suitable to local conditions require less growth stimulation and pest intervention, all in accordance with GAP requirements.

A very important aspect in GAP and HACCP procedures is that of traceability, which allows a product to be followed from orchard to table. The unique orchard ID number can be used in a labelling system that will be included on the labels of all products packed for export.

ArcView GIS proved to be a very effective tool, since it allowed various data sources to be used, as well as the customisation of the GUI and creation of new functions. One drawback of the software that presented itself during the course of the study was ArcView’s inability to display graduated symbols for polygon features. Apart from this, very few problems regarding the software were encountered.

The software application created in the study may prove to be useful to growers, PMO and exporters alike. In order to increase the effectiveness of the project, ways and means of incorporating factors such as non-chemical pest control can be included.



Investigations into the expansion of this project to apply to other crop types can also be undertaken. Ultimately, the World Wide Web (WWW) should be called upon to distribute information to enhance the effectiveness of sharing information. By developing a regional or global database with information such as registered pesticides for different crop types in different countries, all stakeholders involved in the production of fresh produce will have access to the most recent and up to date information.

Using GIS to implement GAP is still a relatively new field of study and the possibilities of expanding this combined field of research to other crop types are virtually endless.

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**APPENDIX A**  
**EUREPGAP GENERAL REGULATIONS**  
**FRESH FRUIT AND VEGETABLES**

# **EUREPGAP Protocol for Fresh Fruit and Vegetables**

English Version



## CONTENTS

0. Introduction
1. Traceability
2. Record Keeping
3. Varieties and Rootstocks
4. Site History and Site Management
5. Soil and Substrate Management
6. Fertiliser Usage
7. Irrigation
8. Crop Protection
9. Harvesting
10. Post-Harvest Treatments
11. Waste and Pollution Management, Recycling and Reuse
12. Worker Health, Safety and Welfare
13. Environmental Issues
14. Complaint Form
15. Internal Audit

<b>0. INTRODUCTION</b>
<b>Scope</b>
This document sets out a framework for Good Agricultural Practice (GAP) on farms which defines essential elements for the development of best-practice for the global production of horticultural products (e.g. fruits, vegetables, potatoes, salads, cut flowers and nursery stock). It defines the minimum standard acceptable to the leading retail groups in Europe, however, standards for some individual retailers and those adopted by some growers may exceed those described. This document does not set out to provide prescriptive guidance on every method of agricultural production.
EUREP members wish to recognise the significant progress already made by many growers, grower groups, grower organisations, local schemes and national schemes in developing and implementing best-practice agricultural systems with the aim of minimising adverse impact on the environment. EUREP members also wish to encourage further work to improve growers capability in this area, and in this respect this GAP framework, which defines the key elements of current agricultural best-practice, should be used as a benchmark to assess current practice, and provide guidance for further development.
GAP is a means of incorporating Integrated Pest Management (IPM) and Integrated Crop Management (ICM) practices within the framework of commercial agricultural production. Adoption of IPM/ICM is regarded by EUREP members as essential for the long-term improvement and sustainability of agricultural production.
EUREP supports the principles of and encourages the use of HACCP (Hazard Analysis Critical Control Points).
It is essential that all organisations involved in the food production chain accept their share of the tasks and responsibilities to ensure that GAP is fully implemented and supported. If consumer confidence in fresh produce is to be maintained, such standards of good agricultural practice must be adopted, and examples of poor practice must be eliminated from the industry.
All growers must demonstrate their compliance with national or international law.
All growers should be able to demonstrate their commitment to: a) maintaining consumer confidence in food quality and safety; b) minimising detrimental impact on the environment, whilst conserving nature and wildlife; c) reducing the use of agrochemicals; d) improving the efficiency of natural resource use; and e) ensuring a responsible attitude towards worker health and safety.
<b>Independent Verification:</b>
The Scheme documents are: <ol style="list-style-type: none"> <li>1. EUREPGAP Protocol as the normative document e.i. the scheme standard with which the grower must comply.</li> <li>2. EUREPGAP General Regulations which sets out the rules by which the scheme will be administered.</li> <li>3. EUREPGAP Control Points and Compliance Criteria which gives specific details on how the grower complies with each of the scheme requirements.</li> <li>4. EUREPGAP Checklist which form the basis of the grower external audit and which the grower must use to fulfil the annual internal audit requirement.</li> </ol>
As described in EUREPGAP General Regulations, this scheme is divided into Major Musts (red background), Minor Musts (yellow background) and Recommendations (green background)
Growers receive their EUREP GAP approval through independent verification from a verification body that is approved by EUREP.



REQUIRED	ENCOURAGED
<b>1. TRACEABILITY</b>	
#1 All the product is traceable to the farm where it has been grown.	
<b>2. RECORD-KEEPING</b>	
<b>2.a. Record Keeping:</b>	
#1 Growers must keep up to date records available to demonstrate that all activities of production comply with GAP as outlined in this document and to help trace the history of products from farm to final consumer. Appropriate records must be kept for a minimum of two years, unless legally required for a longer period. Retrospective records are not required prior to application of EUREPGAP registration.	
<b>3. VARIETIES AND ROOTSTOCKS</b>	
<b>3.a. Choice of Variety or Rootstock:</b>	
	#1 Growers should be aware of the importance of effective crop husbandry in 'mother crops' (e.g. in the production of seed potatoes), which can lead to less intervention in subsequent crops
	#2 Choice of variety or rootstock should meet the specified requirement as agreed between growers and customers with respect to quality standards (e.g. taste, visual appearance, shelf-life, agronomic performance, environmental impact, minimum dependence on agrochemicals).
<b>3.b. Seed Quality:</b>	
	#1 Seed quality should be known before use and a record of the variety name, variety purity, batch number and seed vendor should be kept in a crop diary. Where available, seed certification should be retained.
<b>3.c. Pest and Disease Resistance/Tolerance:</b>	
	#1 Varieties should possess resistance/tolerance to commercially important pests and diseases.
<b>3.d. Seed Treatments and Dressings:</b>	
Seed treatments can be an effective method of controlling pests and diseases, reducing the amount of active ingredients applied to growing crops, and as a strategy for crop protection where foliar sprays are ineffective.	
#1 The use of seed treatments must be justified.	.
<b>3.e. Nursery Stock:</b>	
#1 Purchased nursery stock must be accompanied by officially recognised plant health certification, such as Plant Passports which exist under the EU Plant Health Directive or similar for countries outside the European Union, where available.	#2 Plants should be free of visible signs of pest and disease.
#3 Quality guarantees or certified production guarantees must be kept in the crop diary.	
#4 Plant health quality control systems must be operational for private or in-house nursery propagation.	
#5 Pesticide treatments applied during the plant rearing stage must be recorded.	



REQUIRED	ENCOURAGED
<b>3.f. Genetically Modified Organisms (GMO):</b>	
#1 Planting of any GMO must comply with all existing regulations in the country of production and all existing regulations in the country of the final consumer.	
#2 The use of GMO cultivars must be agreed with individual customers prior to planting.	
#3 Suppliers must inform all customers of any developments relating to the use or production of products derived from genetic modification before engagement.	
<b>4. SITE HISTORY AND SITE MANAGEMENT</b>	
<b>4.a. Site History:</b>	
#1 A recording system must be established for each field, orchard or greenhouse to provide a permanent record of the crops and agronomic activities undertaken at those locations.	
#2 A visual identification or reference system for each field, orchard or greenhouse must be established.	
#3 For all new agricultural sites, a risk assessment must be undertaken, taking into account the prior use of the land and all potential impacts of the production on adjacent crops and other areas.	
#4. The results of the risk assessment analysis must be recorded and used to justify that the site in question is suitable for agricultural production.	
#5 A corrective action plan must be developed setting out strategies to minimise all identified risks in new agricultural sites, such as spray drift or water table contamination.	
<b>4.b. Rotations:</b>	
#1 To maintain soil condition, reduce reliance on agrochemicals and to maximise plant health, growers must recognise the value of crop rotations and seek to employ these whenever practicable.	
#2 Where rotations are not employed, growers must be able to provide adequate justification.	
<b>5. SOIL AND SUBSTRATE MANAGEMENT</b>	
<b>5.a. Soil Type Mapping:</b>	
	#1 Soil maps should be prepared for the farm, which can then be used to plan rotations, planting programmes and growing programmes.
<b>5.b. Cultivation:</b>	
	#1 Mechanical cultivation should be used where proven to improve or maintain soil structure, and to avoid soil compaction.
<b>5.c. Soil Erosion:</b>	
#1 Field cultivation techniques that minimise soil erosion must be adopted.	



REQUIRED	ENCOURAGED
<b>5.d. Soil Fumigation:</b>	
#1 Chemical fumigation of soils must be justified.	#2. Alternatives such as crop rotation, planting of break crops, use of disease resistant cultivars, thermal or solar sterilisation, conversion to soil-free cultivation, and similar techniques must be explored before resorting to use of chemical fumigants
<b>5.e. Substrates:</b>	
#1 For substrates that are not inert, documents must demonstrate its suitability.	#2 For inert substrates (PUR, rockwool, etc.), growers should participate in substrate recycling programs where available.
#3 Where chemicals are used to sterilise substrates for reuse, records of location must be kept.	
#4 Where chemicals are used to sterilise substrates for reuse, date, type of chemical used, method of sterilisation and operator must be kept.	#5 For substrates reuse, steaming should be the preferred option.
<b>6. FERTILISER USAGE</b>	
<b>6.a. Nutrient Requirement:</b>	
	#1 A cropping or soil care plan should be developed to ensure that nutrient loss is minimised.
	#2 The application of fertilisers should be based on nutrient requirements of the crop and on appropriate routine analysis of nutrient levels in the soil, the crop or the nutrient solution.
#3 Fertiliser application, using either mineral or organic fertilisers, must meet the needs of the crops as well as maintaining soil fertility.	
<b>6.b. Advice on Quantity and Type of Fertiliser:</b>	
#1 Growers or their advisers must be able to demonstrate competence and knowledge.	#2 Recommendations for application of fertilisers should be given by competent, qualified advisers holding appropriate and recognised national certification. Where such advisers are unavailable, adequate training in fertiliser usage and application should be undertaken.
<b>6.c. Records of Application:</b>	
#1 All applications of soil and foliar fertilisers must be recorded in a crop diary or equivalent. Records must include: location, date of application, type and quantity of fertiliser applied, the method of application, and operator.	
<b>6.d. Timing and Frequency of Application:</b>	
	#1 The quantity of fertiliser applied and timing of fertiliser application should be carefully considered so as to maximise benefits and minimise losses of fertiliser.
#2 Any application of nitrogen in excess of national or international limits must be avoided.	#3 Quantities of nitrogen to be applied should be calculated from a nitrogen management plan.
<b>6.e. Application Machinery:</b>	
#1 Fertiliser application machinery must be kept in good condition, with annual calibration to ensure accurate delivery of the required quantity of fertiliser.	



REQUIRED	ENCOURAGED
<b>6.f. Fertiliser Storage:</b>	
#1 There are stock records kept up to date and available.	#2 Fertilisers should not be stored in the same room with pesticides. If that is not possible, then the fertilisers and the pesticides must be physically separated and labelled accordingly.
#3 Fertilisers must be stored covered in a clean, dry location where there is no risk of contamination of water sources.	
#4 Fertilisers must not be stored with nursery stock.	
#5 Fertilisers must not be stored with fresh produce	
#6 All hazard and risk areas must be clearly indicated.	
<b>6.g. Organic Manure:</b>	
Organic manure or compost can help improve soil fertility by increasing organic matter content, improve nutrient and water retention and reduce erosion.	
	#1 Organic manure should be stored in an appropriate manner to reduce the risk of contamination of the environment.
#2 The use of raw untreated human sewage sludge is prohibited. Any use of treated human sewage sludge on land destined for agricultural production must be supported by data and/or recognised codes of practice which demonstrate that any carry-over of pathogenic organisms and other components which may have an adverse effect on human health, the quality of the soil, the groundwater or the wildlife are controlled to maintain risks at the lowest possible level.	#3 To avoid pollution by heavy metals or by nitrate leaching, analysis of levels of nutrients, heavy metals and other potential pollutants in the manure, should be completed before application. Proper account must also be taken of the nutrient contribution of manures.
	#4 Manuring in open field cultivation should be based on nutrient management plans.
<b>7. IRRIGATION</b>	
<b>7.a. Predicting Irrigation Requirement:</b>	
	#1 Incorrect usage of water can have a detrimental effect on product quality. To avoid excessive or insufficient water usage, methods of systematically predicting the crop requirement for water should be utilised. Where possible irrigation should be adjusted based on predicted rainfall, plant water use and evaporation. Daily rainfall records for outdoor production may be used to assist in planning irrigation requirements. Growers are recommended to obtain access to regular meteorological forecasts to aid irrigation planning.



REQUIRED	ENCOURAGED
<b>7.b. Irrigation Method:</b>	
	#1 The most efficient and commercially practical water delivery system should be used to ensure the best utilisation of water resources. Flood irrigation systems are discouraged due to excessive wastage of water.
	#2 Consideration should be given to a water management plan to optimise water usage and reduce waste (e.g. systems for re-use, irrigation at night, maintenance of irrigation equipment to reduce leakage, winter storage, collection of rainwater from glasshouses, etc).
	#3 All growers should maintain records of irrigation water usage.
<b>7.c. Quality of Irrigation Water:</b>	
#1 Untreated sewage water must never be used for irrigation.	#2 Based upon risk assessments, irrigation water sources should be analysed at least once a year for microbial, chemical and mineral pollutants by a suitable laboratory. The analysis results should be compared against accepted standards and adverse results acted upon.
<b>7.d. Supply of Irrigation Water:</b>	
	#1 To protect the environment, water should not be abstracted from unsustainable sources. Advice on abstraction should be sought from water authorities.
<b>8. CROP PROTECTION</b>	
<b>8.a. Basic Elements of Crop Protection:</b>	
#1 Protection of crops against pests, diseases and weeds must be achieved with the appropriate minimum pesticide input	
#2 Wherever possible growers must apply recognised IPM techniques on a preventive basis. Non chemical pest treatments are preferred over chemical treatments	#3 Growers are encouraged to understand and adopt IPM systems to control and preserve their productivity and minimise the potential impact of pest control on the environment. Assistance with implementation of such systems should be obtained through training, or advice through advice obtained from grower organisations, research organisations, qualified extension officers, consultants or chemical distributors.



REQUIRED	ENCOURAGED
<b>8.b. Choice of Chemicals:</b>	
#1 The crop protection product utilised must be appropriate for the control required.	#2 Selective products that are specific to the target pest, weed or disease and which have minimal effect on populations of beneficial organisms, aquatic life, workers and consumers and are not detrimental to the ozone layer should be used wherever possible.
	#3 An anti-resistance strategy should be adopted to avoid reliance on any one chemical.
#4 Growers must only use chemicals that are officially registered in the country of use and are registered for use on the crop that is to be protected where such official registration scheme exists, or, in its absence, complies with the specific legislation of the country of destination	
#5. A current list of all products that are used and approved for use on crops being grown must be kept. This list must take account of any changes in pesticide legislation.	
#6. Chemicals that are banned in the European Union must not be used on crops destined for sale in the European Union.	
#7. Growers must be aware of restrictions on certain chemicals in individual countries.	#8 Growers should consult their customers to determine if any additional commercial restrictions exist.
	#9 The label instructions should be followed to ensure successful application, avoid risks to operators, consumers and the environment. Where appropriate, growers may reduce the application frequency specified in the label instructions.
<b>8.c. Advice on Quantity and Type of Pesticide:</b>	
#1 Recommendations for application of pesticides must be given by competent, qualified advisers holding a recognised national certificate or similar.	
#2 Where such advisers are unavailable, growers must be able to demonstrate their competence and knowledge (e.g. through adequate training in pesticide usage and pesticide application).	
#3 The quantity of spray mix calculation must consider: velocity of application, surface area to be covered, pressure of application system.	
<b>8.d. Records of Application:</b>	
#1 All applications of pesticides must always include: crop name, location, date of application, trade name and name of operator.	
#2 Pesticide application records must also include: reason for application, technical authorisation, quantity of pesticide used, application machinery used and pre-harvest interval.	
<b>8.e. Safety, Training and Instructions:</b>	
#1 Workers who handle and apply pesticides must be trained.	#2 Each application should be accompanied by clear instructions or symbols detailing the location of application, chemical dosage and required application technique.



REQUIRED	ENCOURAGED
<b>8.f. Protective Clothing/Equipment:</b>	
#1 Workers must be equipped with suitable protective clothing in accordance with label instructions and appropriate to the posed health and safety risks.	
#2 Growers must be able to demonstrate that they follow label instructions with regard to protective clothing and equipment.	
#3 Protective clothing and equipment must be stored separately from pesticides.	
<b>8.g. Pre-harvest Interval:</b>	
#1 Pre-Harvest intervals must be observed and under no circumstances should the registered pre-harvest interval be ignored.	
<b>8.h. Spray Equipment:</b>	
#1 Spray equipment must be suitable for use on the land in question and be kept in good condition, with annual calibration to ensure accurate delivery of the required quantity of spray.	#2 Participation in an independent sprayer calibration certification scheme is encouraged.
#3 When mixing chemicals, the correct handling and filling procedures, as stated on label instructions, must be followed. The correct quantity of spray mix for the crop to be treated and the proposed treatment type must be calculated, accurately prepared and recorded.	
<b>8.i. Disposal of Surplus Spray Mix:</b>	
	#1 If surplus spray mix does occur, or if there are tank washings, these should be sprayed over an untreated part of the crop, as long as the recommended dose is not exceeded, or sprayed onto designated fallow land, where legally allowed, and records kept for future reference.
<b>8.j. Pesticide Residue Analysis:</b>	
	#1 The frequency of pesticide residue analysis should be based on risk assessment, however, in many cases, pre-harvest sampling and analysis is most effective.
	#2 Residue test results should be traceable to the grower and to the product's production location.
#3 Growers and/or suppliers must be able to provide evidence of residue testing.	
#4 The laboratories used for residue testing are accredited by a competent national authority to good laboratory standard (e.i.: GLP or ISO 17025)	#5 An action plan should be in place in the event of an maximum residue level (MRL) being exceeded.

REQUIRED	ENCOURAGED
<b>8.k. Pesticide Storage:</b>	
#1 Pesticides must be stored in accordance with local regulations and include the following minimum standards:	
#2 Pesticides must be stored in a sound, secure, frost resistant, fire-resistant, well ventilated (in case of walk-in storage) and well lit location which is located away from other materials.	#3 All shelving should be of non-absorbent material.
#4 The pesticide store must be able to retain spillage (e.g. to prevent contamination of water courses).	
#5 There must be adequate facilities for measuring and mixing pesticides.	
#6 There must be emergency facilities (e.g. eye wash, plenty of clean water, a bucket of sand) to deal with operator contamination and accidental spillage.	
#7 Keys and access to the store must be limited to workers with adequate training in the handling of pesticides.	
#8 An accident procedure, a list of contact telephone numbers and the location of the nearest telephone must be available within the immediate vicinity of in the store and next to the nearest telephone.	
#9 Inventory must be kept and readily available.	
#10 All pesticides must be stored in their original package.	
#11 Only chemicals approved for use on the crops produced in the crop rotation must be stored on the farm.	
#12 Powders must be stored on shelves above liquids.	
#13 Signs warning of potential dangers must be placed on access doors.	
<b>8.l. Empty Pesticide Containers:</b>	
#1 Empty pesticide containers must not be re-used and disposal of empty pesticide containers must be in a manner that avoids exposure to humans, and contamination of the environment.	#2 Official collection and disposal systems should be used if available.
#3 Empty containers must be rinsed via the use of an integrated pressure rinsing device on the sprayer, or at least three times with water, and the rinsate returned to the spray tank.	
#4 When rinsed, containers must be pierced to prevent re-use and be adequately labelled according to the rules of a collection system.	
#5 Empty containers must be kept secure until disposal is possible.	
#6 All local regulations regarding disposal or destruction of containers must be observed.	



REQUIRED	ENCOURAGED
<b>8.m. Obsolete Pesticides:</b>	
<b>#1</b> Obsolete pesticides must only be disposed of through a certified or approved chemical waste contractor or supplying company.	
<b>9. HARVESTING</b>	
<b>9.a. Hygiene:</b>	
	<b>#1</b> A hygiene protocol based on a risk analysis should be used to establish hygiene regulations for personnel to prevent physical, microbiological and chemical contamination of produce.
<b>#2</b> Workers must have access to clean toilet and washing facilities in the vicinity of their work.	
<b>#3</b> Workers must receive basic instructions in hygiene before handling fresh produce. Workers must also be made aware of the requirement to notify management of any transferable disease which may render them unfit to work in the vicinity of products destined for human consumption.	
<b>9.b. Packaging on Farm:</b>	
<b>#1</b> Packaging must be stored so as to avoid contamination by rodent, pest, birds, physical and chemical hazards. Where products are field packed, packaging must be removed from the field overnight where a risk of contamination exists.	
<b>#2</b> Reusable crates must be clean and re-cleaned where necessary to ensure they are free from foreign material which may be detrimental to the product and/or consumers health.	
<b>10. POST-HARVEST TREATMENTS</b>	
<b>10.a. Post-harvest Chemicals:</b>	
	<b>#1</b> Use of post-harvest treatments should be minimised.
<b>#2</b> Post-harvest chemicals must only be used in accordance with product label.	
<b>#3</b> Growers must only use chemicals that are officially registered in the country of use, and for use on the crop being protected. Chemicals that are banned in the European Union must not be used on crops destined for sale in the European Union.	
<b>#4</b> A current list of all products that are used and approved for use on crops being grown must be kept. This list must take account of any changes in pesticide legislation. In addition, growers must be aware of restrictions on certain chemicals in individual countries. Growers must consult their customers to determine if any additional commercial restrictions exist.	
<b>#5</b> Growers must be able to demonstrate their competence and knowledge with regard to the application of post-harvest chemicals.	
<b>#6</b> All applications of post-harvest treatments must be recorded in a crop diary or equivalent and include: crop or product, location, date of application, trade name, type and quantity of treatment used and name of operator.	

REQUIRED	ENCOURAGED
#7 All applications of post-harvest treatments must be recorded in a crop diary or equivalent and include the reason for application and machinery used.	
<b>10.b. Post-harvest washing:</b>	
#1 The source of water used for product washing must be potable, and must be filtered if recycled.	#2 Based upon risk assessments, sources of water for post-harvest washing should be analysed by a laboratory (currently accredited to EN 45001 or GLP or its national equivalent or that can demonstrate via documentation that it is in the process of gaining accreditation) for microbial, chemical and mineral pollutants at least once a year. Results of the analysis should be compared to accepted standards and adverse results acted upon.
<b>11. WASTE AND POLLUTION MANAGEMENT, RECYCLING AND RE-USE</b>	
<b>11.a. Identification of Waste and Pollutants:</b>	
	#1 All the possible waste products should be identified in all areas of the farm business (e.g. paper, cardboard, plastic, crop debris, oil, rock wool and other substrates).
	#2 All possible sources of pollution should be identified (e.g. chemicals, oil, fuel, noise, light, debris, pack-house effluent, etc.).
<b>11.b. Waste and Pollution Action Plan:</b>	
	#1 Having identified waste and pollutants, a plan should be developed and implemented, to avoid or reduce wastage and pollution, and whenever possible, avoid the use of land-fill or burning, by recycling the waste. Organic crop debris can be composted on the farm and, where there is no risk of disease carry-over, reused for soil conditioning.



<b>12. WORKER HEALTH, SAFETY AND WELFARE</b>	
<b>12.a. Risk Assessment:</b>	
	<b>#1</b> A risk assessment should be used to develop an action plan to promote safe and healthy working conditions.
<b>12.b. Training:</b>	
<b>#1</b> Formal training must be given to all appropriate workers operating dangerous or complex equipment.	<b>#2</b> Records of training for each employee should be kept in the interests of operator safety.
	<b>#3</b> Workers trained in First Aid should be present in both field and pack-house.
<b>#4</b> Accident and emergency procedures must exist and instructions must be clearly understood by all workers.	<b>#5</b> Accident procedures should be visually displayed and in the appropriate language of the workforce.
<b>12.c. Facilities and Equipment:</b>	
<b>#1</b> First Aid boxes must be present at all permanent sites and in the vicinity of field work.	<b>#2</b> Hazards should be clearly identified by warning signs where appropriate.
<b>12.d. Pesticide Handling:</b>	
	<b>#1</b> Workers undertaking pesticide applications on the farm should receive annual health checks in line with guidelines laid down in local codes of practice.
<b>12.e. Hygiene:</b>	
<b>#1</b> All permanent product packing and storage sites must have adequate pest (including rodent) control measures, particularly in areas for food handling, storage of packaging, storage of pesticides and storage of fertilisers.	<b>#2</b> Workers should receive basic training in hygiene requirements for the handling of fresh produce. The training should outline the need for: hand cleaning, the covering of skin cuts, and the confinement of smoking, eating and drinking to permitted areas, etc.
	<b>#3</b> To avoid establishing a breeding ground for pests and disease, premises should be clear of litter and waste, and have adequate provisions for waste disposal.
<b>12.f. Welfare:</b>	
<b>#1</b> All employment conditions must comply with local and national regulations with regard to wages, workers age, working hours, working conditions, job security, unions, pensions and all other legal and health requirements.	
<b>#2</b> Growers and packers must consult with their customers to ensure compliance with specific company policies regarding worker welfare.	
<b>#3</b> On site living quarters must be habitable and have the basic services and facilities.	



<b>13. ENVIRONMENTAL ISSUES</b>	
<b>13.a. Impact of Farming on the Environment:</b>	
	<b>#1</b> In the light of consumer concern, growers should understand and assess the impact their farming activities have on the environment, and consider how they can enhance the environment for the benefit of the local community and flora and fauna.
<b>13.b. Wildlife and Conservation Policy:</b>	
<b>#1</b> A key aim must be the enhancement of environmental biodiversity on the farm through a conservation management plan. This could be a regional activity rather than an individual one.	
	<b>#2</b> Each grower should have a management of wildlife and conservation policy plan on their property. This Policy should be compatible with sustainable commercial agricultural production and minimise environmental impact of the agricultural activity. Key elements of this plan should be to: <ul style="list-style-type: none"> <li>• Conduct a baseline audit to understand existing animal and plant diversity on the farm. Conservation organisations can help conduct surveys to measure biodiversity and identify areas of concern.</li> <li>• Take action to avoid damage and deterioration of habitats.</li> <li>• Create an action plan to enhance habitats and increase biodiversity on the farm</li> </ul>
<b>13.c. Unproductive Sites:</b>	
	<b>#1</b> Consideration should be given to the conversion of unproductive sites (e.g. low lying wet areas, woodlands, headland strip or areas of impoverished soil) to conservation areas for the encouragement of natural flora and fauna.
<b>14. COMPLAINT FORM</b>	
<b># 1</b> There must be on the site a record available on request of all complaints made known to the supplier relating to all products compliance with requirements of this protocol. There are documents of the actions taken with respect to such complaints and any deficiencies found in products or services.	
<b>15. INTERNAL AUDIT</b>	
<b># 1.</b> The grower must undertake a minimum of one internal audit per annum against the EUREPGAP Standard, this audit must be documented and corrective actions documented and implemented.	



## **APPENDIX B**

### **UML CLASSES**

General
#ID: Number
+Name: String(20)
+Variety: String(20)
+Pest_Resistance: Boolean
+Seed_Treatment: Boolean
+Nursery_Cert: Boolean
+Pest_Treatment: Boolean
+Prior_Use: String(20)
+Plant_Density: Number
+Number_of_Trees: Number
#Area: Number
#Perimeter: Number
+Plant_Date: Date
#Height: Number
+Update
+Geo-Classify
+Calculate Area
+Calculate Perimeter
+Join: Boolean
+Unjoin: Boolean

Soil_Information
#ID: Number
+Lab_Code: String(20)
+pH: Number
+P: Number
+K: Number
+Ca: Number
+Mg: Number
+Na: Number
+Update
+Geo-Classify
+Create Graph
+Join: Boolean
+Unjoin: Boolean

Fertilizer_Application
#ID: Number
+N_(month): Number
+P_(month): Number
+K_(month): Number
+Ca_(month): Number
+Mg_(month): Number
+Na_(month): Number
+Update
+Geo-Classify
+Create Graph
+Join: Boolean
+Unjoin: Boolean

Identifier
#Shape
+ID: Number
+Name: String(20)
+Join: Boolean
+Unjoin: Boolean

Fertilizer_Log
+Date: Date
+Trade_Name: String(20)
+Amount: Number
+Method: String(20)
+Operator: String(20)
+Update

Employees
+Code: Number
+Surname: String(20)
+First_Name: String(20)
+Date_Of_Birth: Date
+Age: Number
+Union: String(20)
+Pension_Fund: String(20)
+First_Aid: Boolean
+Chemical_Operator: Boolean
+Key_Holder: Boolean
+Driver: Boolean
+No_Of_Children: Number
+Job_Description: String(20)
+Status: String(12)
+Update

Scout/Crop_Protection
#ID: Number
+Scout_Default: Number
+Scout_(day+month): Number
+Product_(day+month): Number
+Quantity_(day+month): Number
+Update
+Geo-Classify
+Create Graph
+Join: Boolean
+Unjoin: Boolean

Registered_Products
+Product: String(20)
+Type: String(4)
+Active_Ingredient: Number
+Formulation: String(12)
+Dosage: Number
+Comment: String(12)
+Application: String(20)
+Interval: Number
+Use: String(20)
+Update

Production_(year+month)
#ID: Number
+Production_(day)
+Update
+Join: Boolean
+Unjoin: Boolean



**APPENDIX C**  
**EVALUATION OF THE DATABASE ACCORDING TO**  
**EUREPGAP CATEGORY**

	MUST	SHOULD	YES	NO	N/A
<b>3. VARIETIES AND ROOTSTOCKS</b>					
a. Choice of variety or rootstock		#1			X
	#2.1				X
	#2.2		X		
	#2.3				X
b. Seed Quality		#1	X		
c. Pest and Disease Resistance		#1	X		
	#2				X
d. Seed Treatments and Dressings	#1		X		
e. Nursery Stock	#1		X		
		#2			X
	#3		X		
	#4				X
	#5		X		
f. Genetically Modified Organisms	#1.1				X
	#1.2				X
	#2				X
	#3				X

<b>4. SITE HISTORY AND SITE MANAGEMENT</b>					
a. Site History	#1		X		
	#2		X		
	#3		X		
	#4.1				X
	#4.2				X
b. Rotations	#1				X
	#2		X		

<b>5. SOIL AND SUBSTRATE MANAGAMENT</b>					
a. Soil Mapping		#1.1		X	
		#1.2			X
b. Cultivation		#1			X
c. Soil Erosion	#1				X
d. Soil Fumigation	#1				X
e. Substrates	#1				X
		#2			X
	#3.1				X
	#3.2				X
	#3.3				X
	#3.4				X
	#3.5				X
		#4			X

<b>6. FERTILIZER USE</b>					
a. Nutrient Requirement		#1	X		
		#2	X		
	#3		X		
b. Advice on Quantity and Type of Fertilizer	#1		X		
		#2.1	X		
		#2.2			X
c. Records of Application	#1.1		X		
	#1.2		X		



	MUST	SHOULD	YES	NO	N/A
<b>6. FERTILIZER USE (CONTINUED)</b>					
c. Records of Application (Continued)	#1.3		X		
	#1.4		X		
	#1.5		X		
	#1.6		X		
d. Timing and Frequency of Application		#1.1	X		
		#1.2		X	
	#2		X		
		#3.1	X		
		#3.2	X		
e. Nitrate and Phosphate Levels in Ground Water	#1		X		
		#2.1	X		
		#2.2	X		
		#2.3		X	
		#2.4		X	
f. Application Machinery	#1.1			X	
	#1.2			X	
g. Fertilizer Storage	#1		X		
		#2.1			X
		#2.2			X
	#3.1				X
	#3.2				X
	#3.3				X
	#3.4				X
	#4.1				X
	#4.2				X
	#5				X

**8. CROP PROTECTION**

a. Basic Elements of Crop Protection	#1.1		X		
	#1.2		X		
	#1.3			X	
	#2			X	
		#3			X
b. Choice of chemicals	#1		X		
		#2	X		
		#3	X		
	#4.1		X		
	#4.2				X
	#4.3		X		
	#4.4		X		
	#4.5		X		
	#4.6			X	
		#5		X	
		#6			X
c. Advice on Quantity and Type of Pesticide					
d. Records of application		#1.1	X		
		#1.2	X		
		#1.3	X		
		#1.4	X		
		#1.5		X	

	MUST	SHOULD	YES	NO	N/A
8. CROP PROTECTION (CONTINUED)					
d. Records of application (Continued)	#1.6			X	
	#1.7		X		
	#1.8			X	
	#1.9		X		
	#1.10			X	